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**Ranking of Air Force Heating Plants
Relative to the Economic Benefit
of Coal Utilization**

F. P. Griffin
J. F. Thomas
R. S. Holcomb
J. M. Young

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Engineering Technology Division

RANKING OF AIR FORCE HEATING PLANTS RELATIVE TO
THE ECONOMIC BENEFIT OF COAL UTILIZATION

F. P. Griffin
J. F. Thomas

R. S. Holcomb
J. M. Young

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CONTENTS

| | <u>Page</u> |
|---|-------------|
| LIST OF FIGURES | v |
| LIST OF TABLES | vii |
| LIST OF SYMBOLS, ABBREVIATIONS, AND ACRONYMS | ix |
| ABSTRACT | 1 |
| 1. EXECUTIVE SUMMARY | 1 |
| 1.1 BACKGROUND | 1 |
| 1.2 DESCRIPTION | 2 |
| 1.3 RESULTS AND RECOMMENDATIONS | 3 |
| 2. INTRODUCTION | 6 |
| 2.1 RELATED WORK | 6 |
| 2.2 PURPOSE | 7 |
| 2.3 METHOD | 7 |
| 2.4 LIMITATIONS | 8 |
| 3. PREVIOUS HEATING PLANT SCREENING STUDY | 10 |
| 3.1 SOURCES OF INFORMATION | 10 |
| 3.2 SELECTION OF CANDIDATE AIR FORCE SITES | 11 |
| 3.2.1 Fuel-Use Criteria | 11 |
| 3.2.2 Uniform Present Worth Economic Analysis | 12 |
| 4. NEW INFORMATION FOR 16 CANDIDATE AIR FORCE SITES | 16 |
| 4.1 LOCAL COAL PRICES AND PROPERTIES | 16 |
| 4.2 LOCAL ENVIRONMENTAL REGULATIONS | 16 |
| 4.3 OTHER SITE-SPECIFIC INFORMATION | 17 |
| 5. DESCRIPTION OF COST-ESTIMATION AND ECONOMIC ANALYSES | 19 |
| 5.1 COMPUTER MODEL FOR HEATING PLANT COST ESTIMATION | 19 |
| 5.1.1 Description and Purpose | 19 |
| 5.1.2 Basis of Costs | 21 |
| 5.1.3 Options and Input Parameters | 23 |
| 5.2 COAL-UTILIZATION PROJECT ASSUMPTIONS | 27 |
| 5.2.1 Steam/HTHW Output Capacity | 27 |
| 5.2.2 Combustion Technologies | 31 |
| 5.3 COMPUTER MODEL FOR LCC ANALYSIS | 33 |
| 5.3.1 Air Force Financing | 35 |
| 5.3.2 Private Financing | 37 |
| 5.3.3 Definitions of Figures-of-Merit | 39 |

| | |
|---|----|
| 6. RESULTS OF RANKING STUDY | 43 |
| 6.1 VALUES OF INPUT VARIABLES | 43 |
| 6.1.1 Cost-Estimation Variables | 43 |
| 6.1.2 Economic Variables | 45 |
| 6.2 RANKING BY BENEFIT/COST RATIO | 48 |
| 6.2.1 Air Force Financing and Ownership | 48 |
| 6.2.2 Private Financing and Ownership | 53 |
| 6.2.3 Overall Observations | 56 |
| 6.3 SENSITIVITY TO SELECTED ECONOMIC ASSUMPTIONS | 59 |
| 6.3.1 Ranking by Discounted Payback Period | 59 |
| 6.3.2 Effect of Discount Rate | 61 |
| 6.4 SUMMARY OF LEADING SITES FOR COAL UTILIZATION | 61 |
| 6.4.1 Arnold AFS | 61 |
| 6.4.2 Kelly AFB | 63 |
| 6.4.3 Grand Forks AFB | 64 |
| 6.4.4 Minot AFB | 65 |
| 6.4.5 Robins AFB | 65 |
| 6.4.6 Plattsburgh AFB | 66 |
| 6.4.7 McGuire AFB | 67 |
| 7. CONCLUSIONS AND RECOMMENDATIONS | 69 |
| REFERENCES | 71 |
| APPENDIX. AIR FORCE BASE INFORMATION SUMMARIES | 73 |

LIST OF FIGURES

| <u>Figure No.</u> | <u>Title</u> | <u>Page</u> |
|-----------------------|--|-------------|
| 5.1 | Illustration of monthly average heating load | 29 |
| 5.2 | Illustration of ideal capacity factor as a function of boiler output capacity | 30 |
| 5.3 | Time-dependent multiplier applied to annual main- tenance costs | 37 |

LIST OF TABLES

| <u>Table No.</u> | <u>Title</u> | <u>Page</u> |
|----------------------|---|-------------|
| 1.1 | Summary of Air Force-financed project results for the most cost-effective technology | 4 |
| 1.2 | Summary of privately financed project results for the most cost-effective technology | 4 |
| 3.1 | Heating plants meeting fuel-use criteria | 13 |
| 3.2 | Cost and economic parameters used in the UPW analysis | 14 |
| 5.1 | Example capital investment cost spreadsheet for micronized coal | 21 |
| 5.2 | Example operating and maintenance cost spreadsheet for micronized coal | 22 |
| 5.3 | Input parameters for calculation of project costs | 23 |
| 5.4 | Usual positions of boiler modification switches | 25 |
| 5.5 | Coal refit technologies affected when boiler modification switches are turned on | 25 |
| 5.6 | Economic assumptions used in the LCC analysis | 34 |
| 5.7 | Example discounted cash flow spreadsheet for Air Force financing | 36 |
| 5.8 | Example discounted cash flow spreadsheet for private financing | 38 |
| 5.9 | Example LCC summary spreadsheet for Arnold Air Force Station | 40 |
| 6.1 | Coal-conversion project definition parameters | 44 |
| 6.2 | Fuel escalation scenarios | 47 |
| 6.3 | Air Force-financing results with ranking according to "nominal values" | 49 |
| 6.4 | Summary of Air Force-financing results for best coal technologies | 52 |
| 6.5 | Private-financing results with ranking according to "nominal values" | 54 |
| 6.6 | Summary of private-financing results for best coal technologies | 57 |
| 6.7 | Summary of ranking results for Air Force and private financing | 58 |

| | | |
|-----|---|----|
| 6.8 | Discounted payback periods for selected Air Force-financed projects | 60 |
| 6.9 | Effect of discount rate on Air Force-financing results for zero fuel escalation | 62 |

LIST OF SYMBOLS, ABBREVIATIONS, AND ACRONYMS

| | |
|--------|---|
| AAC | Alaskan Air Command |
| AEO | Annual Energy Outlook |
| AFB | Air Force base |
| AFESC | Air Force Engineering and Services Center |
| AFLC | Air Force Logistics Command |
| AFS | Air Force station |
| AFSC | Air Force Systems Command |
| ATC | Air Training Command |
| AU | Air University |
| Btu | British thermal unit |
| BBtu | billion Btu |
| CY | calendar year |
| DEIS | Defense Energy Information System |
| DOD | U.S. Department of Defense |
| DOE | U.S. Department of Energy |
| EIA | Energy Information Administration |
| ESP | electrostatic precipitator |
| FBC | fluidized-bed combustor |
| FY | fiscal year |
| gal | gallon |
| HHV | higher heating value |
| h | hour |
| HTHW | high-temperature hot water |
| kWh | kilowatt hour |
| \$K | thousand dollars |
| lb | pound |
| LCC | life-cycle cost |
| MAC | Military Airlift Command |
| MAJCOM | major command |
| MBtu | million Btu |
| MCP | Military Construction Program |
| MFBI | Major Fuel Burning Installation |
| ORNL | Oak Ridge National Laboratory |

| | |
|-------|---------------------------------|
| O&M | operating and maintenance |
| ROM | run-of-mine |
| ROR | rate of return |
| SAC | Strategic Air Command |
| SOYD | sum-of-the-years digits |
| UPW | uniform present worth |
| USAFA | United States Air Force Academy |

RANKING OF AIR FORCE HEATING PLANTS RELATIVE TO THE ECONOMIC BENEFIT OF COAL UTILIZATION

F. P. Griffin R. S. Holcomb
J. F. Thomas J. M. Young

ABSTRACT

The Defense Appropriations Act of 1986 requires the Department of Defense to use an additional 1.6 million tons of coal per year at their U.S. facilities by 1995. It also states that the most economical fuel should be used at each facility. To comply with this act, the United States Air Force requested Oak Ridge National Laboratory to evaluate the feasibility and economics of using coal at Air Force heating plants that currently burn natural gas and/or oil. A life-cycle cost analysis of 16 heating plants was performed, and the results were used to rank the facilities from best to worst according to their potential for economical utilization of coal. As many as 12 different coal combustion technologies were analyzed at each Air Force site. Also, two types of financing and three levels of fuel escalation were examined in the analysis for a total of six economic scenarios. The heating plants at Arnold, Kelly, Grand Forks, Minot, Robins, Plattsburgh, and McGuire Air Force bases were consistently identified as the top seven facilities for coal conversion, but the actual amount of cost savings will be strongly dependent on future fuel escalation rates.

1. EXECUTIVE SUMMARY

1.1 BACKGROUND

The Defense Appropriations Act of 1986 (PL 99-190 Section 8110) requires the U.S. Department of Defense (DOD) to use an additional 1,600,000 short tons per year of coal at their U.S. facilities by 1995. It also states that the most economical fuel should be used at each facility. To comply with this act, the United States Air Force requested Oak Ridge National Laboratory (ORNL) to evaluate the feasibility and economics of replacing gas- and/or oil-firing at Air Force heating plants with coal-firing.

In a previous study by ORNL,¹ commercial and near-commercial coal-burning technologies applicable to conversion of Air Force facilities were reviewed. The capital, operating, and maintenance costs for these coal technologies were estimated generically for typical heating plant installations, from which cost equations were formulated and put into a cost-estimating computer model for use in subsequent tasks. For comparison, the computer model also included cost estimates for gas- and oil-fired boilers.

In a second study by ORNL,² Air Force installations that currently burn significant quantities of gas and/or oil were reviewed to determine a list of 15 to 20 candidate sites for conversion to coal. Experience has shown that small heating plants (annual average fuel usage <30 MBtu/h) will be unable to burn coal economically in the near future. Using this fuel-use criteria as a cutoff point, in conjunction with a simple economic analysis based on the use of uniform present worth factors, a list was developed consisting of 16 Air Force sites that could potentially use coal with a cost savings.

1.2 DESCRIPTION

In this report, the 16 Air Force sites mentioned above were evaluated further to determine their relative potential for cost savings through coal utilization. The types of projects examined were ones that incorporate coal-firing to meet only the base load of a given heating plant; it was assumed that gas and/or oil would continue to be used for peaking and backup requirements. Commercial and near-commercial coal combustion technologies were evaluated, including technologies for both refitting and replacing existing boilers. As many as 12 coal technology options were considered for each Air Force site.

An economic analysis was performed using the cost-estimating computer model that was developed during an earlier task of the project, together with a newly developed life-cycle cost (LCC) computer model. The economic results were evaluated by calculating a benefit/cost ratio for each coal-conversion option at each site. In this study, the term "benefit" is used to refer to cost avoidance (i.e., the cost of continued operation of an existing system) rather than cost savings (i.e.,

the difference between the cost of an existing system and the cost of a new system). The benefit/cost ratio is therefore defined as the LCC of the portion of the existing gas- or oil-fired system that would be displaced by coal, divided by the LCC of the new coal-fired system. The 16 Air Force sites were then ranked from best to worst according to the benefit/cost ratios for the most cost-effective coal technology at each site.

The LCC results were found to be very sensitive to the assumed fuel escalation rates; therefore three separate escalation scenarios were examined. These three escalation assumptions represent high, medium, and low cases for escalation of gas and oil prices relative to coal prices. The high fuel escalation case was developed from DOD guidelines for energy-dependent economic analyses.³ These DOD escalators are based directly on the *Annual Energy Outlook 1986* report, published by the Energy Information Administration (EIA) of the U.S. Department of Energy (DOE).⁴ The DOD fuel escalation scenario just described will be referred to as the "nominal" case.

The second fuel escalation scenario was developed from the recently published *Annual Energy Outlook 1987* report.⁵ The 1987 projections for fuel escalation are somewhat lower than the 1986 projections, and they represent a medium fuel escalation scenario. This second set of escalators is referred to as the "AEO 1987" fuel escalators. A third escalation scenario was also examined; simply assuming zero escalation of fuel prices.

In addition to the three assumptions for fuel escalation, two types of financing were examined: Air Force-owned and -financed projects and privately owned and financed projects. The combinations of fuel escalation and type of financing produce six economic scenarios that have been examined. Tables 1.1 and 1.2 summarize the ranking results for the most cost-effective coal-conversion project (highest benefit/cost ratio) at each site.

1.3 RESULTS AND RECOMMENDATIONS

Tables 1.1 and 1.2 show that the three fuel escalation scenarios have a very significant effect on the calculated benefit/cost ratios for

Table 1.1. Summary of Air Force-financed project results
for the most cost-effective technology

| Base | "Nominal" fuel escalation | | "AEO B7" fuel escalation | | Zero fuel escalation | | Projected coal use (tons/year) |
|------------------------|------------------------------|------|-----------------------------|------|---------------------------|------|--------------------------------------|
| | Benefit/ cost ratio | Rank | Benefit/ cost ratio | Rank | Benefit/ cost ratio | Rank | |
| Arnold | 2.141 | 1 | 1.616 | 1 | 1.191 | 1 | 23,650 |
| Kelly | 1.798 | 2 | 1.369 | 2 | 1.022 | 3 | 16,010 |
| Minot | 1.743 | 3 | 1.348 | 3 | 1.018 | 4 | 12,100 |
| Robins | 1.737 | 4 | 1.330 | 5 | 1.003 | 6 | 17,270 |
| McGuire | 1.643 | 5 | 1.264 | 7 | 0.950 | 7 | 13,220 |
| Grand Forks | 1.632 | 6 | 1.345 | 4 | 1.057 | 2 | 13,500 |
| Plattsburgh | 1.562 | 7 | 1.281 | 6 | 1.011 | 5 | 16,340 |
| Pease ^a | 1.540 | 8 | 1.196 | 8 | 0.917 | 10 | 13,060 |
| Tinker | 1.532 | 9 | 1.151 | 11 | 0.840 | 14 | 45,600 |
| Elmendorf ^b | 1.527 | 10 | 1.146 | 12 | 0.851 | 12 | 154,370 |
| Hill | 1.486 | 11 | 1.141 | 14 | 0.848 | 13 | 23,560 |
| Scott | 1.473 | 12 | 1.141 | 13 | 0.854 | 11 | 13,730 |
| Dover | 1.434 | 13 | 1.188 | 9 | 0.947 | 8 | 12,470 |
| Andrews | 1.431 | 14 | 1.185 | 10 | 0.945 | 9 | 12,940 |
| USAF Academy | 1.339 | 15 | 1.038 | 15 | 0.790 | 16 | 24,990 |
| Hanscom | 1.267 | 16 | 1.035 | 16 | 0.828 | 15 | 20,140 |
| Total | | | | | | | 433,110 |

^aLCC results for Pease may be optimistic because of questionable access to inexpensive rail delivery for coal.

^bLCC results for Elmendorf may be optimistic because of questionable availability of inexpensive coal.

Table 1.2. Summary of privately financed project results
for the most cost-effective technology

| Base | "Nominal" fuel escalation | | "AEO B7" fuel escalation | | Zero fuel escalation | |
|------------------------|------------------------------|------|-----------------------------|------|---------------------------|------|
| | Benefit/ cost ratio | Rank | Benefit/ cost ratio | Rank | Benefit/ cost ratio | Rank |
| Arnold | 1.946 | 1 | 1.468 | 1 | 1.077 | 1 |
| Kelly | 1.608 | 2 | 1.223 | 2 | 0.909 | 6 |
| Robins | 1.586 | 3 | 1.213 | 4 | 0.911 | 5 |
| Minot | 1.567 | 4 | 1.211 | 5 | 0.912 | 4 |
| McGuire | 1.482 | 5 | 1.140 | 7 | 0.854 | 7 |
| Grand Forks | 1.474 | 6 | 1.213 | 3 | 0.951 | 2 |
| Plattsburgh | 1.425 | 7 | 1.168 | 6 | 0.918 | 3 |
| Elmendorf ^a | 1.386 | 8 | 1.039 | 11 | 0.767 | 11 |
| Pease ^b | 1.384 | 9 | 1.075 | 8 | 0.820 | 10 |
| Tinker | 1.304 | 10 | 0.979 | 12 | 0.711 | 14 |
| Dover | 1.295 | 11 | 1.073 | 9 | 0.851 | 8 |
| Andrews | 1.287 | 12 | 1.066 | 10 | 0.846 | 9 |
| Scott | 1.263 | 13 | 0.978 | 13 | 0.729 | 13 |
| Hill | 1.252 | 14 | 0.961 | 14 | 0.710 | 15 |
| Hanscom | 1.168 | 15 | 0.954 | 15 | 0.760 | 12 |
| USAF Academy | 1.152 | 16 | 0.894 | 16 | 0.678 | 16 |

^aLCC results for Elmendorf may be optimistic because of questionable availability of inexpensive coal.

^bLCC results for Pease may be optimistic because of questionable access to inexpensive rail delivery for coal.

coal-conversion projects. There is much uncertainty associated with future fuel prices, and caution should be used when interpreting the results. A large number of projects appear to be economically viable when the DOD fuel escalators ("nominal" case) are used, and only a small number appear economical if zero fuel escalation is assumed. There are no profound differences observed between the Air Force- and private-financing cases; the benefit/cost ratios are only slightly higher for Air Force financing.

Although the fuel escalation assumptions can greatly affect the benefit/cost ratios, some consistency is observed regarding the ranking of the Air Force sites. Arnold is consistently ranked first for all six economic scenarios in Tables 1.1 and 1.2. The sites ranked 2 through 7 include Kelly, Grand Forks, Minot, Robins, Plattsburgh, and McGuire, although their respective order changes. These seven sites are recommended as the leading candidates for project implementation.

The potential coal usage listed in Table 1.1 shows that, with the possible exception of Elmendorf, a relatively small amount of coal would be used by any individual project when compared to the DOD target of 1,600,000 tons/year. Projects at the top seven Air Force bases would consume only about 112,000 tons/year. Other types of projects that would use greater amounts of coal, such as cogeneration or increasing heating loads through distribution system extensions, should be examined.

Noneconomic factors such as Air Force energy security, aesthetics, and possible effects on base missions have not been considered up to this point. Obviously, these types of considerations must be factored into future decision-making processes.

2. INTRODUCTION

ORNL is supporting the Air Force Coal Utilization/Conversion Program by providing the Air Force Engineering and Services Center (AFESC) with a defensible plan to meet the provisions of the Defense Appropriations Act of 1986 (PL 99-190 Section 8110). This Act directs the Air Force to implement the rehabilitation and conversion of Air Force central heating plants [either steam or high-temperature hot water (HTHW)] from natural gas- and/or oil-firing to coal-firing, if a cost savings can be realized. This directive applies to Air Force installations in the contiguous 48 states and Alaska.

2.1 RELATED WORK

ORNL has been involved in the Air Force Coal Utilization/Conversion Program since 1986. In a previous report by ORNL for AFESC,¹ the full range of commercial and near-commercial coal-burning technologies applicable to the conversion of Air Force central heating plants was reviewed. General descriptions and characterization of each technology are presented including the degree of commercialization or development, combustion efficiency, environmental performance, applications, and limitations. The capital and operating costs for these technologies have been estimated for generic or typical heating plant installations. These cost estimates were formulated into algorithms and put into a spreadsheet computer program for use in subsequent studies.

In another report by ORNL,² Air Force installations currently burning significant quantities of gas and/or oil were reviewed. This previous report was a screening study to find the installations most suitable for coal use. Heating plants at 16 installations were identified as having enough potential for coal utilization with an economic benefit to warrant further analysis. The 16 Air Force bases previously identified are considered further in this report. More details of the previous screening study are explained in Chap. 3.

A complementary study for AFESC was completed recently by ORI Inc. and C. H. Guernsey and Co.⁶ That study examined central heating plants at 34 selected Air Force bases. Leading candidate heating plants were

identified for a few specific coal-conversion scenarios. Those scenarios fit into two categories: (1) complete conversion of the existing steam/HTHW systems to stoker coal-firing by boiler conversion or replacement, and (2) building coal-fired cogeneration systems sized to meet peak electric loads. Stoker-firing was the only coal technology considered in the ORI Inc./C. H. Guernsey and Co. report.

2.2 PURPOSE

The primary objective of this study is to establish a priority list of Air Force sites with the best potential for cost-effective coal utilization. A small number of installations are identified as leading sites for coal-utilization project implementation.

The analysis work provides a quantitative ranking of the heating plants at each site according to the economic benefit of coal utilization. In order to accomplish this ranking, a wide variety of coal-burning technologies have been evaluated in this study. Heating plant conversion may include alteration of existing boilers with the addition of certain equipment to allow coal-firing, or adding a new coal-fired boiler system to the heating plant. Cogeneration of heat and electricity will be considered in a separate report.

2.3 METHOD

Available information about Air Force central heating plants has been collected and organized to examine conversion to coal-firing. Emphasis was put on determining steam/HTHW loads, electric loads, existing boiler design and condition, current fuel costs, local environmental regulations, and site-specific factors that will affect conversion project costs and technology selection. The 16 candidate heating plants identified in the previous screening study² were examined more closely, and LCC economic analyses were performed for each heating plant. The plants were then ranked according to the results of the economic analyses.

A variety of coal technology options were examined for each site. These technology options are described in a previous ORNL report¹ and

discussed very briefly later in this report. A computer model was developed to generate itemized costs for each coal-burning technology based on project size, capacity factor, fuel costs, coal specifications, SO₂ removal requirements, electricity costs, and other variables. Cost estimates can be generated for as many as seven boiler refit technologies and six types of replacement boilers. For comparison, the cost of continued operation of the existing gas/oil-fired system that would be replaced by coal-firing is also calculated. The cost of the gas/oil system represents the expenditures that can be avoided by switching to coal.

For each Air Force site, conversion project specifications, such as steam/HTHW output capacity and type of coal technology, were selected on the basis of economics and site-specific limitations. Because high capacity factors are generally required for coal systems to be economical, the typical result is that only a portion of the maximum steam/HTHW load should be met with coal-firing, while the remaining steam/HTHW load should be met with gas/oil peaking units. This is a notable contrast to the ORI Inc./C. H. Guernsey and Co. report, which used the assumptions of 100% coal-firing capability for all heating plant conversions and stoker-firing as the only technology option.

Two types of project financing are analyzed in this report. One scenario represents an Air Force-owned project using Military Construction Program (MCP) funds, and the other scenario assumes that a private company builds, owns, and operates the heating plant. The economic assumptions and their effects on the results are discussed in Chaps. 5 and 6.

2.4 LIMITATIONS

This study has certain limitations relating to site and fuel cost data. Some of the site-specific information is either unknown or incomplete, and therefore some of the project options and possible problems are unknown. Detailed architectural, engineering, and environmental studies will be required before implementing an actual project.

Another condition that cannot be predicted accurately is future changes in fuel prices. This is an especially important consideration

in this study because it is likely that coal, gas, and oil prices will all escalate at different rates. Fuel prices greatly affect the LCCs of the existing gas/oil systems as well as all of the potential coal-conversion projects. The LCC estimates must be updated as fuel price conditions change.

Despite some limitations, the cost-estimation and economic analyses described in this report have provided an effective way to identify and rank Air Force central heating plants that have the best potential for coal utilization. The information presented in this report can be used for future studies leading to actual project implementation at selected heating plants.

3. PREVIOUS HEATING PLANT SCREENING STUDY

A previous report² was aimed at narrowing the number of gas- or oil-burning Air Force facilities to be considered as viable coal-utilization candidates. ORNL reviewed and analyzed data pertaining to gas- and/or oil-fired central heating plants and documented the results in that report. The objective of the screening study was to develop a list of the 15 to 20 Air Force sites with the best potential for conversion to coal.

3.1 SOURCES OF INFORMATION

Reliable information characterizing the Air Force heating plants was necessary to accomplish the objectives of the previous screening study. The information needed for each Air Force base included current fuel use, heating load profile, fuel prices, possible coal delivery methods, boiler design and condition, status and condition of peripheral equipment, and electric power consumption and price.

ORI Inc. and C. H. Guernsey and Co. report. A major source of information was the report entitled *Air Force Coal Conversion Phase III Discovery and Fact Finding Study* by ORI Inc. and C. H. Guernsey and Co.⁶ In that report, 34 Air Force bases were examined by using questionnaires, telephone contacts, and personal visits to gather information needed to assess coal use at the central heating plants. Other sources of information, such as previous Air Force assessments, were also used to supplement those efforts to obtain information. This study was particularly helpful because current gas, oil, and electricity prices were obtained, as well as load information, heating plant capacity-rating data, and other up-to-date information.

MFBI survey. Useful information concerning many important Air Force heating plants was found in the results of a 1980 inventory of Air Force boilers larger than 10 MBtu/h output capacity. This inventory was part of the Federal Facilities Power Plant and Major Fuel Burning Installation Survey (MFBI Survey) requested by DOE by authority of the Power Plant and Industrial Fuel Use Act of 1978.

Much information that is useful for analysis of the central heating plants was included in this MFBI Survey. The major drawbacks were that some Air Force base surveys were incomplete or contained conflicting information. The MFBI Survey information is dated, and a few heating plants have been upgraded or the heating loads have changed somewhat in the interim.

Other sources. Several other sources of information were also utilized for the previous screening study, including contacts with knowledgeable individuals, applicable Defense Energy Information System (DEIS) data, several internal studies of Air Force heating plants, and a boiler data base developed by the U.S. Army's Construction Engineering Research Laboratory from Hartford Steam Boiler Co. data. This data base was helpful in cross-checking the existence and capacity ratings of individual boilers. The internal Air Force studies provided 1985 and 1986 load information (steam/HTHW and electric) for selected Air Force bases.

3.2 SELECTION OF CANDIDATE AIR FORCE SITES

3.2.1 Fuel-Use Criteria

In the previous screening study, a list was made of Air Force gas-and/or oil-burning heating plants identified as significant fuel users. Information pertaining to these heating plants was then examined more closely. Large plants were sought because coal utilization is much more competitive at large sizes. Favorable economics for coal use depends on displacing large amounts of gas and/or oil with coal. Furthermore, capital, operating, and maintenance costs for coal-fired boiler equipment have less impact on total costs as the size of the boiler increases (see discussion of economy of scale in Sect. 5.2.1).

A list was developed identifying 26 heating plants at 24 Air Force facilities that have a reported annual fuel use >260 BBtu (annual average fuel consumption >30 MBtu/h). Based on experience, it was judged that facilities using less energy than this cutoff point could not be viable candidates for coal use in the near term. All heating plants for which at least one source of data indicated a fuel use >260

BBtu/year are included in Table 2.1. Note that two heating plants are treated as a single system at Andrews Air Force Base (AFB) because they feed into a common distribution system.

3.2.2 Uniform Present Worth Economic Analysis

In the previous screening study, a relatively simple economic analysis was used to identify where coal would be economically competitive with the current fuel being used. This process allowed the elimination of ten additional heating plants from further consideration by verifying that they were very poor candidates for coal use. In this way, the study identified 16 gas- and/or oil-fired heating plants at 16 Air Force bases that should be investigated further to determine their potential for coal utilization.

The previous economic analysis was not as sophisticated or detailed as the one presented later in this report. In the previous analysis, the annual fuel, operating, and maintenance costs were multiplied by a uniform present worth (UPW) factor to determine their present values. The assumption was made that these series of annual costs would remain uniform over the life of the project. Projects were chosen for each heating plant based on conversion of only a portion of the plant to coal-firing; one or two boilers at each heating plant were assumed to be refitted for coal-firing or replaced with new coal-fired boilers. Each project was optimized to be near the most cost-effective size. The cost-estimation and economic assumptions used in the UPW analysis are listed in Table 3.2. The economic assumptions resulted in a UPW factor of 9.427.

The capital investment requirements, operating and maintenance (O&M) costs, and fuel costs for each simulated project were estimated in the previous screening study with the aid of a cost-estimation computer model. This model has been reused in this ranking study, but different values are used for the input parameters to reflect new information about the Air Force bases. The cost-estimation model is described in Sect. 5.1 of this report.

Each heating plant was evaluated according to the economic benefit of conversion to coal. Those plants that showed the least promise for

Table 3.1. Heating plants meeting fuel-use criteria

| Base | Major command | Building No. | Number of units | Type of fuel ^a | Plant output capacity (MBtu/h) | 1978 | | 1979 | | 1985 fuel use (MBtu) | ORI/ Guernsey survey (MBtu) |
|--------------|---------------|--------------|-----------------|---------------------------|--------------------------------|-----------------|------------------|-----------------|------------------|----------------------|-----------------------------|
| | | | | | | Fuel use (MBtu) | Lim ^b | Fuel use (MBtu) | Lim ^b | | |
| | | | | Pri | Sec | | | | | | |
| Elmendorf | AAC | 22-004 | 6 | C | 2 | 2673 | | 2694 | | 1074 | 2616 |
| Hill | AFLC | 260 | 8 | C | 2 | 1331 | | 1087 | | 300 | |
| Hill | AFLC | 825 | 3 | C | 2 | 150 | | | | 540 | 504 |
| Kelly | AFLC | 376 | 5 | C | 2 | 597 | | 570 | | 340 | |
| McClellan | AFLC | 367 | 2 | C | 5 | 129 | C | 170 | C | 865 | 872 |
| Robins | AFLC | 177 | 5 | C | 2 | 948 | | 903 | | | |
| Tinker | AFLC | 3001 | 3 | C | 2 | 1262 | | 1411 | | | |
| Tinker | AFLC | 208 | 4 | C | 2 | 671 | | 647 | | | |
| Arnold | AFSC | 1411 | 4 | C | 2 | 599 | | 589 | | | 642 |
| Hanscom | AFSC | 1201 | 4 | C | 6 | 739 | | 751 | | | 856 |
| Keesler | ATC | 409 | 5 | C | 2 | 84 | | | | 300 | 300 |
| Lowry | ATC | 361 | 4 | C | 2 | 222 | | 269 | | 199 | 411 |
| Maxwell | AU | 1410 | 5 | C | 2 | 338 | | 308 | | 557 | 557 |
| Andrews | HAC | 1515/1732 | 8 | C | 5 | 527 | | 546 | | 175 | 160 |
| Charleston | HAC | 431 | 4 | C | 6 | 276 | | 229 | | 407 | 407 |
| Dover | HAC | 617 | 4 | C | 6 | 511 | | 444 | | 344 | 325 |
| McChord | HAC | 734 | 3 | C | 2 | 326 | | 361 | | 488 | 809 |
| McGuire | HAC | 2101 | 6 | C | 2 | 811 | | 801 | | 347 | 436 |
| Scott | HAC | 45 | 4 | C | 6 | 493 | | 495 | | 555 ^c | 480 ^c |
| Grand Forks | SAC | 423 | 5 | C | 6 | 548 | | 611 | | 463 | 463 |
| Minot | SAC | 413 | 6 | C | 6 | 584 | | 644 | | 370 | 370 |
| Pease | SAC | 124 | 2 | C | 6 | 433 | 6 | 337 | 6 | 825 | 825 |
| Pleattsburgh | SAC | 2658 | 6 | C | 6 | 848 | | 801 | | 312 | 312 |
| Whiteman | SAC | 140 | 3 | C | 6 | 216 | | 311 | | 319 | 319 |
| Wurtsmith | SAC | 305 | 4 | C | 6 | 319 | | 329 | | | |
| USAF Academy | USAF | 2560 | 4 | C | 5 | 800 | ? | 800 | ? | | 562 |

^aFuels: Pri - primary, Sec - secondary, C - natural gas, 6 - No. 6 (residual) oil, 5 - No. 5 oil, 2 - No. 2 (distillate) oil, P - propane, N - none.

^bLimitations on fuel-use data: C - gas use only; 6 - No. 6 oil use only, ? - data is missing or suspect.

^cAn electric boiler system was in use. An estimate of fossil fuel that would otherwise be consumed was calculated assuming a 75% boiler efficiency.

Table 3.2. Cost and economic parameters used
in the UPW analysis

Cost-estimating assumptions

| | |
|--|--------------------------|
| Price of stoker coal | \$1.75/MBtu |
| Price of run-of-mine coal | \$1.50/MBtu |
| Price of coal/water slurry | \$3.00/MBtu |
| Price of coal/oil slurry | \$3.50/MBtu |
| Price of natural gas | Local price |
| Price of No. 2 distillate oil | \$4.71/MBtu (\$0.65/gal) |
| Price of No. 6 residual oil | \$3.67/MBtu (\$0.55/gal) |
| Labor rate | \$5,000/man-year |
| Ash disposal price | \$10/ton |
| Electric price, \$/kWh | Local price |
| No active SO ₂ removal required | |

Economic assumptions

Air Force-owned and -operated project
 Economic life is 30 years
 Real discount rate is 10%
 UPW factor applied to fuel and O&M costs is 9.427
 All capital is invested at the beginning of the project
 No salvage value after 30 years
 No local property taxes and insurance
 No real escalation of fuel and O&M costs
 General inflation effects are negligible

being candidates from an economic standpoint were reviewed further by considering annual fuel use, annual electric use, and electric price (cogeneration possibilities). For McClellan, the strict California environmental regulations were also considered. Using this information to make judgements, the heating plants at McClellan, Keesler, Lowry, Maxwell, Charleston, McChord, Whiteman, and Wurtsmith were eliminated along with plant No. 825 at Hill and plant No. 208 at Tinker. Hill and Tinker have larger heating plants remaining in the list.

The results of the screening study produced a list of 16 heating plants at 16 Air Force bases to be given further consideration. Each of the remaining sites has a single heating plant that may be a viable candidate for a conversion project, with the exception of the two plants

at Andrews that are treated as a single system because they are connected to a common distribution system. The relative potential for coal utilization at these 16 Air Force installations is the subject of the remainder of this report.

4. NEW INFORMATION FOR 16 CANDIDATE AIR FORCE SITES

This chapter describes the efforts since the heating plant screening study was completed. It was deemed necessary to produce a more in-depth analysis of the remaining 16 Air Force sites to accurately rank them according to the economic benefit of coal utilization. Many of the differences between the previous screening study and this current ranking effort are highlighted in this chapter.

4.1 LOCAL COAL PRICES AND PROPERTIES

It is important to understand the prices and characteristics of the coals available at each prospective site. To obtain such information, a large number of coal suppliers and transportation companies were contacted. Information was requested for both stoker-grade and run-of-mine (ROM) coals.

Each request to coal suppliers asked for the mine mouth price (more precisely, the price of coal brought to a specific rail or truck loading point) and the following characteristics for each coal: higher heating value; content of ash, sulfur, nitrogen, and fines; top and bottom size; ash-softening temperature; swelling index; and grindability index. The transportation costs were estimated by the coal supplier and/or the railroad companies that would be involved. Generally, rail delivery is cheaper when the delivery distance is significant (>200 miles). When rail shipment was not possible or inappropriate, truck delivery rates were estimated.

The use of locally available coal properties and prices in this study represents a significant improvement over the previous screening study, which assumed uniform coal prices of \$1.50/MBtu for ROM coal and \$1.75/MBtu for stoker coal. The coal properties and prices that were used for each Air Force site are summarized in the Appendix.

4.2 LOCAL ENVIRONMENTAL REGULATIONS

To understand the environmental control requirements for each Air Force site under consideration, the appropriate state agencies were

contacted. Most of the 15 states contacted sent copies of the latest regulations and other helpful material. Another highly utilized source was the *Environmental Reporter*,⁷ which publishes state environmental regulations.

Federal environmental regulations applicable to fossil-fuel-burning installations were also reviewed. Generally, the federal regulations only apply to coal-burning systems with fuel input capacities >100 MBtu/h. However, if the site is located in, or near, a zone ruled to be in noncompliance with ambient SO₂, NO_x, or particulate standards, special federal regulations can apply regardless of size. Information to determine if a given Air Force base is within a noncompliance zone was available from other ORNL studies.

In the previous screening study, the costs of SO₂ or NO_x reduction were not included in the analysis, although particulate removal costs were included in all cases (baghouses were assumed necessary). The appropriate environmental regulations have been taken into consideration in this ranking study. For most sites it was found that when the fuel input capacity is below 100 MBtu/h, there are either no SO₂ emission regulations or low-sulfur coal will be sufficient to meet the SO₂ regulations. Furthermore, current coal combustion technology will achieve sufficient NO_x control in most cases. The effect that environmental regulations have in each specific case is discussed in the Appendix.

4.3 OTHER SITE-SPECIFIC INFORMATION

Other site-specific information not considered in the previous screening study has been included in this study. This is the result of more information being obtained and also implementation of a more detailed analysis. The availability of FY 1986 fuel-use data led to the revision of the expected capacity factors for some heating plants. The expected capacity factor is a key parameter when calculating the LCC of a coal-utilization project. Another source of information was from a separate effort at ORNL concerning energy security at Air Force installations.⁸ Also, a draft copy of the information in the Appendix of this

report has been sent to the appropriate major command (MAJCOM) headquarters for their review and comments. Their written and verbal responses contained new and updated information for some of the bases.

Some Air Force sites currently have no room for a coal pile on the base or perhaps only have sufficient space at a site remote from the central heating facility. This affects the type of coal technologies that can be used at the site. Another space problem that can occur is that there is very little room near the existing boilers because of the presence of other equipment and other buildings. If a space shortage is severe enough, the retrofit technologies that require large pieces of equipment to be located near the existing boiler will be penalized or eliminated. Such space shortages were not accounted for in the previous report but are considered in this study.

The site-specific considerations that affect the economic analysis of each heating plant are described in the information summaries provided in the Appendix for each of the 16 Air Force sites.

5. DESCRIPTION OF COST-ESTIMATION AND ECONOMIC ANALYSES

5.1 COMPUTER MODEL FOR HEATING PLANT COST ESTIMATION

5.1.1 Description and Purpose

In a previous study by ORNL for the Air Force,¹ coal combustion technologies found to be applicable to Air Force central heating plants were reviewed and evaluated. As a part of that previous work, O&M and capital cost equations were developed for the many coal technology options that could be employed at a heating plant. O&M cost equations for firing gas or oil at a central heating plant were also developed for comparison. A computer model, based on these cost equations, was developed to estimate heating plant costs for each of 13 different coal technology options and for gas- and oil-firing. The costs generated for the coal technology options can be compared with each other and with the costs of continued firing of gas or oil. A much more detailed discussion of the development of the heating plant cost-estimating equations can be found in the previous report prepared for the Air Force Engineering and Services Center.¹

The 13 coal-utilizing technologies included in the cost-estimating model are divided into the following two categories:

| <u>Refit technologies</u> | <u>Replacement boilers</u> |
|---------------------------------|----------------------------|
| Micronized coal-firing | Packaged shell stoker |
| Slagging pulverized coal burner | Packaged shell FBC* |
| Modular FBC add-on unit | Field-erected stoker |
| Return to stoker-firing | Field-erected FBC |
| Coal/water slurry | Pulverized coal boiler |
| Coal/oil slurry | Circulating FBC |
| Low-Btu gasifier | |

The refit technologies reuse as much of the existing boiler equipment as possible. In a micronized coal system, the coal is pulverized

*FBC - fluidized-bed combustor.

to a size much smaller than ordinary pulverized coal, and it is burned directly in the existing boiler. In a slagging system, pulverized coal is burned in a small, high-temperature, cyclone burner that is connected to the existing boiler. In a modular FBC system, part of the steam/HTHW is generated in an add-on bubbling FBC unit, and the existing boiler is used as a waste heat recovery unit. The return to stoker-firing option can only be considered if the existing boiler was originally designed for stoker coal. In slurry systems, the coal/water and coal/oil mixtures are burned directly in the existing boiler. In a gasifier system, stoker coal is gasified with air in an add-on unit and the hot, low-Btu gas is burned in the existing boiler.

The replacement boilers reuse only the existing water treatment system and the steam/HTHW distribution system. For the stoker and bubbling FBC systems, both packaged and field-erected units have been examined. The packaged units are factory-built, shell (fire-tube) boilers that are small enough to be shipped by rail. The field-erected units are larger, water-tube boilers. For the pulverized coal and circulating FBC systems, only field-erected, water-tube boilers have been examined.

The costs of emission control systems for particulates, NO_x , and SO_2 are included in the cost-estimating model. All 13 coal technologies are assumed to require baghouses to meet the particulate emission regulations. Particulate control beyond cyclone-type devices is required virtually everywhere in the United States, and baghouses are judged to be the most cost-effective and appropriate technology. NO_x emissions are assumed to be controlled with conventional combustion control systems for all coal technologies. The need for active SO_2 removal systems varies from location to location, and the type of SO_2 control system required depends on the coal technology. Costs associated with SO_2 control can be included or excluded in the cost-estimating model on a case-by-case basis. The assumptions about SO_2 control systems are discussed later in Sect. 5.1.3.

The computer model consists of two corresponding spreadsheets for each of the 13 coal technologies, one for estimating the capital investment and another for estimating O&M costs. Each spreadsheet calculates

an itemized cost table, such as the examples shown in Tables 5.1 and 5.2. The purpose of using this itemized cost table format is to generate very consistent and comparable cost estimates for each technology considered. Any calculated project costs can easily be examined in detail. The personal computer software package used to develop the costing program is Framework II, by Ashton-Tate Corp.

5.1.2 Basis of Costs

The cost-estimating algorithms are based on recent cost studies, vendor and user information, and applicable reported costs of coal-based projects. The cost equations for commercialized technologies were developed from a literature review and extensive previous work at ORNL.

Table 5.1. Example capital investment cost spreadsheet for micronized coal

| | |
|------------------------------|----------------------|
| Technology: MICRONIZED | Size (MBtu/hr) |
| COAL BURNER - REFIT TO | Output steam = 72.00 |
| EXISTING BOILER | No. of units = 1 |
| 20-200 MBTU/HR | Output/unit = 72 |
| Multiple unit multiplier = 1 | |

| ITEM | SCALING FACTOR | COSTS IN k\$ |
|-----------------------------|-------------------|--------------|
| Site work & foundations | .50 | 24. |
| Boiler modifications | .50 | 12. |
| Scot blowers | .60 | 0. |
| TAS micronized comb. system | .52 | 176. |
| Boiler house modification | .50 | 24. |
| Fuel handling & storage | .40 | 781. |
| No bottom ash system | | 0. |
| Ash handling | .40 | 298. |
| Electrical | .80 | 100. |
| Baghouse | .80 | 520. |
| Subtotal | | 1935. |
| Indirects (30%) | | 581. |
| Contingency (20%) | | 503. |
| Total for each unit | | 3019. |
| Grand total | | 3019. |

Table 5.2. Example operating and maintenance cost spreadsheet for micronized coal

Technology: MICRONIZED COAL BURNER REFIT TO EXISTING BOILER
SIZE 10-200 MBTU/HR

| | |
|------------------------------------|-------------------------|
| Total output (MBtu/hr) = 72.00 | COAL, LIMESTONE, ASH |
| Number of units converted = 1 | Ash fraction = .10 |
| Unit output (MBtu/hr) = 72.00 | S fraction = .015 |
| Fuel to steam efficiency = .80 | HHV (Btu/lb) = 12000.00 |
| Capacity factor = .72 | Ton coal/yr = 23652.00 |
| Ash disposal price(\$/ton) = 10.00 | Ca/S ratio = .00 |
| Electric price(cents/kWh) = 4.50 | Inert fraction = .05 |
| Labor rate (k\$/yr) = 35.00 | Ton sorbent/yr = .0 |
| Limestone price (\$/ton) = 20.00 | Waste/sorbent = .858 |
| | Ton ash/yr = 2365.2 |

| CATEGORY | SCALING FACTOR | COST IN k\$ |
|------------------------------|-------------------|----------------|
| Direct manpower (f) | .18 | 557.9 |
| Repair labor & materials (f) | .36 | 374.3 |
| Electricity (f) | 1.00 | 36.2 |
| Electricity inc. baghse (v) | 1.00 | 74.1 |
| Baghouse (f) | .36 | 29.8 |
| Limestone (v) | 1.00 | .0 |
| Ash disposal (v) | 1.00 | 23.7 |
| Nonfuel O&M total | | 1095.92 |

A large amount of information concerning coal-, gas-, and oil-fired systems can be found in a report published by the U.S. Army Corps of Engineers, Construction Engineering Research Laboratory,⁹ which includes background information and cost equations developed by ORNL for a variety of coal-based systems and other energy technologies.

Cost data for technologies that are "emerging" or not yet commercialized are either unreliable or unavailable. Therefore, costs of such systems were developed by reviewing each emerging technology and comparing with conventional coal technologies. When comparing these technologies, several cost items (equipment, maintenance, manpower) will often be identical or very similar. The differences between technologies have been explored to develop cost estimates that are consistent and comparable. Costs for certain items were developed through contact with and visits to vendors and users. Actual prices and costs were obtained (rather than budgetary estimates) whenever possible. More

information concerning the development of the cost equations can be found in Refs. 1 and 9.

5.1.3 Options and Input Parameters

A list of input parameters for the cost-estimating model is given in Table 5.3. Numerical values are given for those parameters that are

Table 5.3. Input parameters for calculation of project costs

| | | |
|--|--|-------------------|
| Project definition parameters | | |
| 1. Total project heat output capacity, MBtu/h | | Variable |
| 2. New boiler system expected capacity factor, % | | Variable |
| 3. Number of existing units to be refit, integer number | | Variable |
| 4. SO ₂ control option, on/off switch | | Variable |
| 5. Soot blower option, on/off switch | | Variable |
| 6. Tube-bank modification option, on/off switch | | Variable |
| 7. Bottom ash pit option, on/off switch | | Variable |
| O&M cost parameters | | |
| 8. Hydrated lime price, \$/ton | | 41.60 |
| 9. Ash disposal price, \$/ton | | 10.40 |
| 10. Electric price, c/kWh | | Variable |
| 11. Labor rate, \$K/(man-year) | | 36.40 |
| 12. Limestone price, \$/ton | | 20.80 |
| Fuel prices | | |
| 13. Natural gas, \$/MBtu | | Variable |
| 14. No. 2 oil, \$/MBtu | | 4.71 (\$0.65/gal) |
| 15. No. 6 oil, \$/MBtu | | 3.67 (\$0.55/gal) |
| 16. ROM coal, \$/MBtu | | Variable |
| 17. Stoker coal, \$/MBtu | | Variable |
| 18. Coal/water mixture, \$/MBtu | | 3.00 |
| Coal properties | | |
| 19. Ash fraction | | Variable |
| 20. Sulfur fraction | | Variable |
| 21. HHV, Btu/lb | | Variable |
| Limestone/lime properties | | |
| 22. Inert fraction | | 0.050 |

assumed to have fixed values. The numerical values of the other parameters vary from site to site as is discussed later in Sect. 6.1.1. These input parameters and variables are defined in this section.

Project size. Three important input variables are used to define the project size. The project thermal output capacity (size) must be specified, and the expected capacity factor for the new coal-fired system is associated with a given output capacity. The way that output capacity and expected capacity factor were determined in this study is explained in Sect. 5.2.1. Inherent to choosing the capacity of any project involving refit technologies is the number of existing boilers to be converted to coal-firing. These three variables (numbered 1-3 in Table 5.3) are project specific and must be uniquely determined for each case.

SO₂ control. Based on the applicable regulations at each site, for each project it must be determined if the available coals can be burned without using special SO₂ control methods. SO₂ emissions will be controlled passively if an inexpensive low-sulfur coal is available. However, when active SO₂ removal is needed, an "on/off switch" input variable can be turned on to add costs for SO₂ control to all coal combustion technologies. This includes added costs for capital equipment, lime or limestone, labor, electricity, etc. The active SO₂ removal techniques assumed in the computer model are limestone injection for micronized coal-firing, slagging combustors, and the two slurry technologies; limestone addition for all fluidized-bed combustion technologies; lime spray-dry flue gas scrubber systems for all stoker and pulverized coal technologies; and chemical H₂S stripping from coal gasification product gas.

Existing boiler modifications. Some refit technologies require up to three types of modifications to the existing boilers: addition of soot blowers, adding a bottom ash pit (ash removal) system, and boiler heat transfer tube-bank modifications. The decision of when to include these modifications is a function of the design of the existing boilers and the type of coal-utilization technology employed. The procedure used for adding the costs of the three boiler modifications is illustrated in Tables 5.4 and 5.5 and described below. Also, background information for this decision-making process can be found in Ref. 1.

Table 5.4. Usual positions of boiler modification switches

| Existing boiler design | Soot blower option | Tube-bank modification option | Bottom ash pit option |
|------------------------|--------------------|-------------------------------|-----------------------|
| Coal | Off | Off | On |
| Residual oil | Off | On | On |
| Distillate oil | On | On | On |

Table 5.5. Coal refit technologies affected when boiler modification switches are turned on

| Coal refit technology | Soot blowers added | Tube-bank modification included | Bottom ash pit system added |
|------------------------------------|--------------------|---------------------------------|-----------------------------|
| Micronized coal-firing | Yes | No | No |
| Slagging pulverized coal combustor | Yes | No | Yes |
| Modular fluidized-bed unit | Yes | No | Yes |
| Return to stoker-firing | No | No | Yes |
| Coal/water slurry-firing | Yes | Yes | Yes |
| Coal/oil slurry-firing | Yes | Yes | Yes |
| Coal gasification | No | No | No |

The computer model has three on/off switch variables (numbered 5-7 in Table 5.3) that control whether or not the costs of a particular boiler modification are included in the total costs. Table 5.4 shows how the switch positions are usually selected as a function of the boiler design. For example, if an existing boiler was designed for residual oil, it is normally assumed that the boiler already has soot blowers, but requires tube-bank modifications and the addition of an ash pit. Deviations from these usual switch positions are sometimes necessary based on more detailed information pertaining to a given boiler.

When the boiler modification switches are turned on, the appropriate costs are automatically added by the computer model to some, but not all, of the refit technologies. Table 5.5 illustrates which coal

refit technologies are affected by the three boiler modification switches. For example, when a bottom ash pit must be added, costs are added to all of the refit technologies except micronized coal-firing and coal gasification.

O&M cost parameters. A number of parameters that affect nonfuel O&M costs are inputs to the cost-estimating computer model. Table 5.3 gives the values used for limestone price, lime price, ash disposal price, and labor rate. The values of these four parameters were fixed throughout this study and include a 4% adjustment from 1987 to 1988 dollars. The assumption of a uniform labor rate in the United States may be somewhat simplified, but more detailed information was not available. Locally reported values were used for price of electricity at each Air Force base.

Fuel prices. The values for fuel prices (numbered 13-18 in Table 5.3) must be specified in current dollars. These current prices may escalate with time; different escalation scenarios can be modeled by the LCC computer program. The current prices used for No. 2 and No. 6 oils were assumed to be uniform in all regions of the country and equal to the DOD stock fund prices. It is assumed that the higher heating value (HHV) of No. 2 oil is 138,000 Btu/gal and the HHV of No. 6 oil is 150,000 Btu/gal. For lack of better information, a uniform price was also used for coal/water slurry. The cost of coal/water slurry would no doubt have regional variations, but such variations cannot really be known at this time. Any price used for slurry fuels is questionable.

Local prices that vary from region to region were used for natural gas, ROM coal, and stoker coal. Gas prices reflect recent reported costs from the Air Force bases under consideration. Coal prices were determined from the study described in Sect. 4.1. The prices used were for the lowest-cost ROM and stoker coals with acceptable properties.

Coal and limestone properties. Coal properties were taken from the coal selection study described in Sect. 4.1. The properties used were for the lowest-cost ROM and stoker coals with acceptable characteristics. The inert fraction of limestone and lime (caused by impurities) was specified as a single value equal to 5% by weight. It was also

assumed that lime would be hydrated with one water molecule per calcium atom.

5.2 COAL-UTILIZATION PROJECT ASSUMPTIONS

A series of choices must be made to define the scope of a coal-utilization project at a given heating plant. Section 5.1.3 already has touched on some of these choices by defining the computer input parameters and variables for the cost-estimation model. The assumptions involved in selecting actual values for some of these input variables are discussed further in this section. The procedure for choosing the size of a coal project is explained in Sect. 5.2.1, and the method for selecting applicable coal technologies at each site is explained in Sect. 5.2.2.

5.2.1 Steam/HTHW Output Capacity

When examining coal-utilization projects at a particular heating plant, it is desirable to find the optimum (most economical) size for the coal-firing equipment. The size of a coal project is defined here as the design steam/HTHW output capacity in MBtu/h. To understand how the steam/HTHW output capacity was selected for the coal-fired systems at each Air Force base, it is helpful to examine the trade-offs involved.

When compared to gas/oil-fired boilers, coal systems require much higher capital investments and are more costly to operate and maintain. A coal system can realize an overall cost savings only if coal is sufficiently less expensive than gas or oil. A basic trade-off exists between gas/oil systems with high fuel prices and coal systems with low fuel prices but high capital and O&M costs. The optimum size of a coal-conversion project is influenced by this trade-off, which is discussed below along with some other important considerations.

Economy of scale. The costs of coal-fired boilers are affected by what is sometimes termed the "economy of scale." This means that as the design capacity of a boiler or boiler plant is increased (without major design changes), the accompanying capital investment required and annual

O&M costs also increase, but at a slower rate. The following values illustrate this principle:

| | Capital investment (\$) | Nonfuel O&M annual cost (\$) |
|---------------------------|-------------------------------|------------------------------------|
| 25,000-lb/h stoker boiler | 3,250,000 | 761,000 |
| 50,000-lb/h stoker boiler | 4,900,000 | 934,000 |

These example cost estimates are for single-boiler heating plants operating at 60% annual capacity factor and are for illustration only. It is seen that doubling the boiler system size increases the costs but does not double them. This economy of scale effect causes coal systems to be less competitive for small applications and more competitive for large applications, when compared to gas/oil systems.

Capacity factor vs size. The capacity factor is defined in this report as the total amount of heat that a boiler produces in 1 year divided by the total amount of heat that the boiler could produce if it operated at its design output capacity (maximum continuous rating) for the entire year. The Air Force heating plants examined in this report have capacity factors that range from ~25% to 40%. These low capacity factors are a result of redundancy built into most of the central heating plants. Apparently this excess capacity ensures very high heating source reliability, even at peak load conditions.

An important question that must be answered is how much plant capacity should be converted to coal-firing to achieve the best economic results. The answer depends largely on the heating load profile of a particular heating plant, but the general rule is that only a small portion of the plant should be converted. Any newly installed coal-fired equipment should be used as much as is practical to minimize the effect of capital and O&M costs. All heating load that is not provided by coal-firing should be supplied by the remaining gas- or oil-fired equipment.

The principle of "diminishing returns" is at work here. As the size of a proposed coal system is increased, the expected capacity

factor for that system will decrease. For each incremental increase in the output capacity of a coal system, the incremental savings of fuel costs will decrease. Even with the economy of scale effect, a point is reached where the additional capital and O&M costs of a larger coal system are not offset by the potential fuel cost savings.

Accurate information about the load profile of an existing heating plant is needed to determine the optimum size for a coal-conversion project. The type of information available for Air Force heating plants is shown in Fig. 5.1, which illustrates an example of monthly average heating load. From this monthly average load data, "ideal" capacity factors were calculated as a function of boiler output capacity, as is shown in Fig. 5.2. These ideal capacity factors must be adjusted to account for daily and hourly load fluctuations and equipment repair time. For this study, the ideal capacity factors calculated from monthly data were multiplied by a factor of 0.9. A small table that

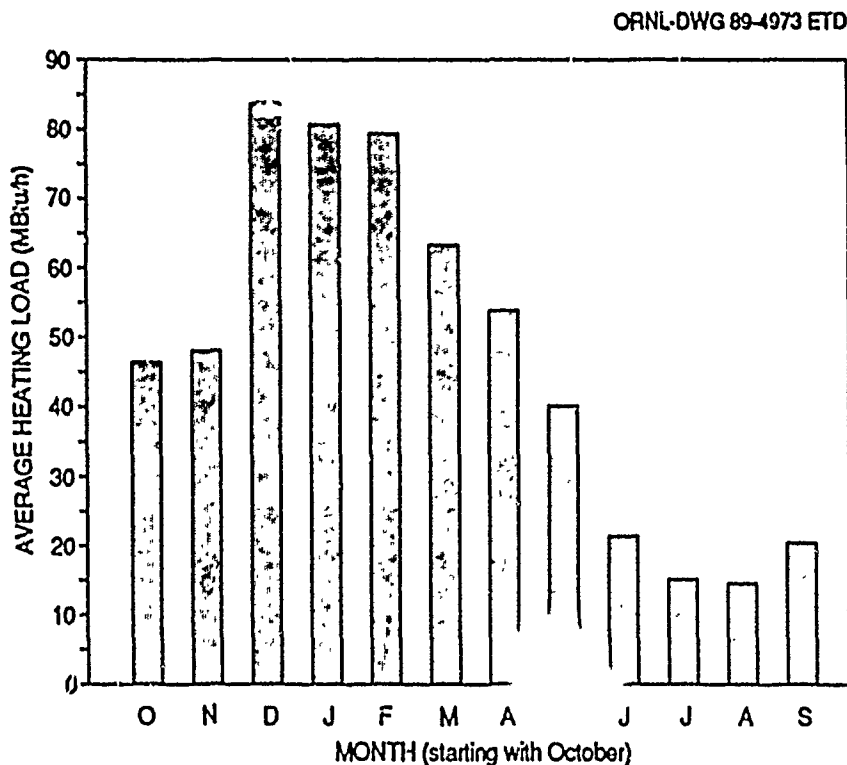


Fig. 5.1. Illustration of monthly average heating load.

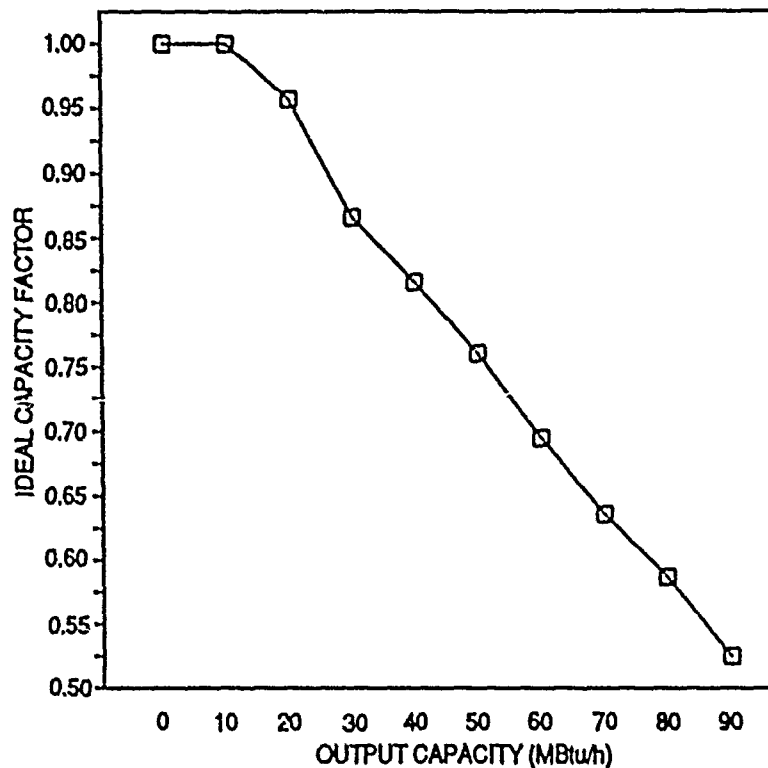


Fig. 5.2. Illustration of ideal capacity factor as a function of boiler output capacity.

lists expected capacity factor vs coal project size is included in each Air Force base information summary in the Appendix.

Size and design of existing boilers. One of the conclusions of the previous heating plant screening study² was that the coal refit technologies tend to be more economical than the boiler replacement technologies. Because of that trend, the analysis in this ranking study concentrated more on the refit technologies. The capacities of the existing boilers at a heating plant therefore had a strong influence on the selection of output capacity. Only one or two of the existing boilers would generally be chosen for conversion to coal-firing. This obviously limited the selection of possible output capacities to discrete steps.

The design of the existing boilers also influenced the selection of output capacity. If the existing boilers were originally designed for either coal or residual (No. 6) oil, it was assumed that the boilers

have enough volume in the furnace to operate at their full design capacity with any of the coal refit technologies, if the boilers are modified as discussed in Sect. 5.1.3. However, boilers that were originally designed for distillate (No. 2) oil tend to have smaller furnace volumes with tightly spaced tubes. In addition to the boiler modifications discussed in Sect. 5.1.3, it was assumed that No. 2 oil-fired boilers would require a capacity derating of 20% to accommodate the coal combustion equipment. The boilers that were actually selected for coal refit and their capacity before and after conversion are explained in the Air Force base information summaries in the Appendix.

Emission regulations. At a few Air Force sites, the applicable SO₂ emission regulations affected the choice of project size. The federal New Source Performance Standards regulate SO₂ emissions from coal-burning equipment only if fuel input ratings are 100 MBtu/h or greater (assuming the location is in compliance with federal ambient air quality standards). When the state regulations allow coal to be burned without SO₂ removal, there is an economic incentive to keep a coal system smaller than 100 MBtu/h of fuel input (equivalent to about 75 or 80 MBtu/h of steam/HTHW output). If the design capacities of the existing boilers in a heating plant are larger than this cutoff value, then it was sometimes advantageous to derate the boilers to eliminate the need for active SO₂ removal systems. The effects of the applicable environmental regulations on each simulated project are discussed in the Air Force base information summaries in the Appendix.

5.2.2 Combustion Technologies

The 13 coal-utilizing technologies included in the cost-estimating model are discussed in Sect. 5.1.1. Only a subset of those technologies was evaluated for each particular heating plant site, and the technologies that were included or excluded were determined on a case-by-case basis. Technologies were only eliminated if a valid reason for removal was determined. The general reasoning behind the elimination of certain technologies is described here. Information pertaining to the selection of appropriate technology options for each Air Force base is found in the information summaries in the Appendix.

Coal/oil slurry. Coal/oil mixture technology was eliminated entirely from this study for a number of reasons. The cost estimates for the slurry technologies (both coal/oil and coal/water) were based on the assumption that near-term commercialization would make large quantities of slurry fuels available regionally or locally at competitive prices. However, there is currently very little interest (or research and development work) in coal/oil slurries for either industrial or utility applications. This is in direct contrast to coal/water slurry-firing, which is currently receiving much more attention. It seems that coal/oil slurries have a much smaller chance of becoming commercialized than coal/water slurries.

Coal/oil slurry-firing was judged to be much less attractive than coal/water slurry-firing if oil prices are assumed to escalate significantly faster than coal prices. Because ~50% of the coal/oil slurry heating value comes from oil, the benefit of coal/oil slurry-firing decreases rapidly as oil prices rise relative to coal prices.

There have been some technical problems specifically associated with coal/oil slurries, one of which is NO_x control. Flame temperatures have been reported to be high, causing excessive amounts of thermally produced NO_x . This type of problem is not seen with coal/water slurry-firing. Also it may not be possible to use a baghouse for particulate control with coal/oil slurries because of the possibility of blinding the bag material. An electrostatic precipitator (ESP) may be required instead of a baghouse. The disadvantage is that an ESP is a more costly technology for the size of the systems under consideration.

It is acknowledged that coal slurries containing both oil and water are being developed and marketed at this time. This type of slurry was not examined directly in this study. However, coal/water/oil mixtures are judged to be similar to coal/water slurries because only a small amount of the total heating value (<30%) comes from the oil.

Return to stoker-firing. One of the coal retrofit options is to reuse stoker-firing in a boiler that was originally designed for stoker-firing. If none of the existing boilers at a heating plant were designed for stoker-firing, then this retrofit technology must obviously be eliminated from consideration.

Space limitations. At some Air Force bases, some of the technologies could not be considered as viable alternatives because of site-specific space limitations. The two types of space considerations examined in this study were (1) space for the coal combustion and coal-handling equipment and (2) space for a coal pile. Space must be available inside a boiler house for any new boilers, boiler modifications, add-on combustion equipment, coal feeding equipment, and any coal preparation equipment such as pulverizers. The boiler house can be expanded if necessary. Space is required outside a boiler house for the day storage silos and coal conveyors. The coal pile should be located no more than a few hundred meters from the boiler house, and there must be ample room for the rail or truck unloading station as well as a good supply of coal.

The retrofit technologies are affected when space is limited in and around the existing boiler house. The slagging combustor, modular FBC, return to stoker, and gasifier technologies were dropped from the analysis first because they require the greatest amount of equipment space in the boiler house. The micronized coal equipment occupies somewhat less room, and this technology could be retained in a few special situations when the other dry coal technologies were eliminated. All of the above dry coal technologies were eliminated when there is no room for a coal pile near the existing boiler house. The coal/water slurry technology was analyzed at all of the Air Force bases because it was assumed to require no more room than an oil-fired boiler.

The replacement technologies are affected by space limitations at both the existing boiler house and other locations on the base. All six replacement technologies could be considered at almost all of the Air Force bases. If the replacement boilers had to be located at a new heating plant, then it was assumed that the costs of connecting the new boilers to the existing distribution system would be negligible.

5.3 COMPUTER MODEL FOR LCC ANALYSIS

In addition to the cost-estimation model, a computer model devoted to LCC analysis was also developed. The LCC model has two main parts: a

discounted cash flow spreadsheet and an LCC summary spreadsheet. In the cash flow spreadsheet, the capital and O&M costs (including fuel) are distributed over time, while the value of money is assumed to be time-dependent (i.e., the cash flows are discounted). The calculated LCC of a project is the summation of these discounted cash flows over the economic life of the project. In the LCC summary spreadsheet, the LCCs of the proposed coal-fired boilers are compared to the LCC of the existing gas/oil system.

Two major financing scenarios were included in the economic analysis: one for Air Force ownership and operation of the coal equipment and one for private ownership and operation. The economic assumptions used in the LCC analysis are listed in Table 5.6 for both the Air Force- and private-financing scenarios. The primary differences between the Air Force- and private-financing scenarios are in the way that capital costs and taxes are treated. Four of the parameters in Table 5.6 (general inflation, fuel escalation, discount rate, and return on investment) are labelled as variables. The values used in the LCC analysis for these four variables are discussed later in Sect. 6.1.2.

Table 5.6. Economic assumptions used in the LCC analysis

| Parameter | Air Force financing | Private financing |
|--|------------------------|----------------------|
| Project start year, start of construction | 1990 | 1990 |
| Construction period, year | 1 | 1 |
| Economic life of project, years | 30 | 30 |
| Salvage value at end of economic life | 0 | 0 |
| Time-dependent curve for maintenance costs | U-shaped | U-shaped |
| Inflation and discounting base year | 1988 | 1988 |
| General inflation rate | Variable | Variable |
| Fuel real escalation rates | Variable | Variable |
| Real discount rate | Variable | Variable |
| Equity, percent of capital investment | Not applicable | 100% |
| Before-tax real return on investment | Not applicable | Variable |
| Amount of working capital, months | Not applicable | 2 |
| SOYD depreciation life, years | Not applicable | 15 |
| Local property tax and insurance rate, % | 0 | 2 |
| Federal income tax rate, % | Not applicable | 34 |
| Investment tax credits | Not applicable | None |

5.3.1 Air Force Financing

The Air Force-financing assumptions in Table 5.6 can be explained most easily with the aid of the example discounted cash flow spreadsheet shown in Table 5.7. Coal-fired boiler projects are assumed to start at the beginning of 1990 with a 1-year construction period. Coal-firing begins in 1991 and continues for 30 years through the end of 2020. All dollar amounts in the cash flow spreadsheet are in as-spent thousands of dollars (k\$) that are inflated from a base year of 1988. However, in the example in Table 5.7, as-spent thousands of dollars are actually equal to constant 1988 thousands of dollars because the spreadsheet was calculated for zero general inflation, as is seen in the "GENERAL INFLATION INDEX" line.

The cash flow spreadsheet can accommodate fuel prices with escalation rates that differ from the general inflation rate as is seen in the "FUEL INFLATION INDEX" line of Table 5.7. Fuel inflation is calculated from the same 1988 base year as general inflation. The fuel costs shown in the "FUEL" line are determined by estimating the annual fuel cost in the 1988 base year and then multiplying by the fuel inflation index for each year.

The maintenance costs in the "MAINTENANCE" line of the cash flow spreadsheet are treated in a special way. The annual maintenance costs generated by the cost-estimation model are adjusted by the time-dependent multiplier shown in Fig. 5.3 when they are entered into the cash flow spreadsheet. The U-shaped curve accounts for extra costs that occur because of infant failures during the first 3 years of heating plant operation and old-age failures during the last 8 years.

The "TOTAL COST TO AIR FORCE" line of Table 5.7 is the sum of the annual capital and O&M costs. The present value of these total costs are calculated in the "DISCOUNTED AF TOTAL" line by discounting back to the 1988 base year. The LCC of the project appears in the lower right-hand corner of the cash flow spreadsheet.

Table 5.7. Example discounted cash flow spreadsheet for Air Force financing (17 middle years are bidden)

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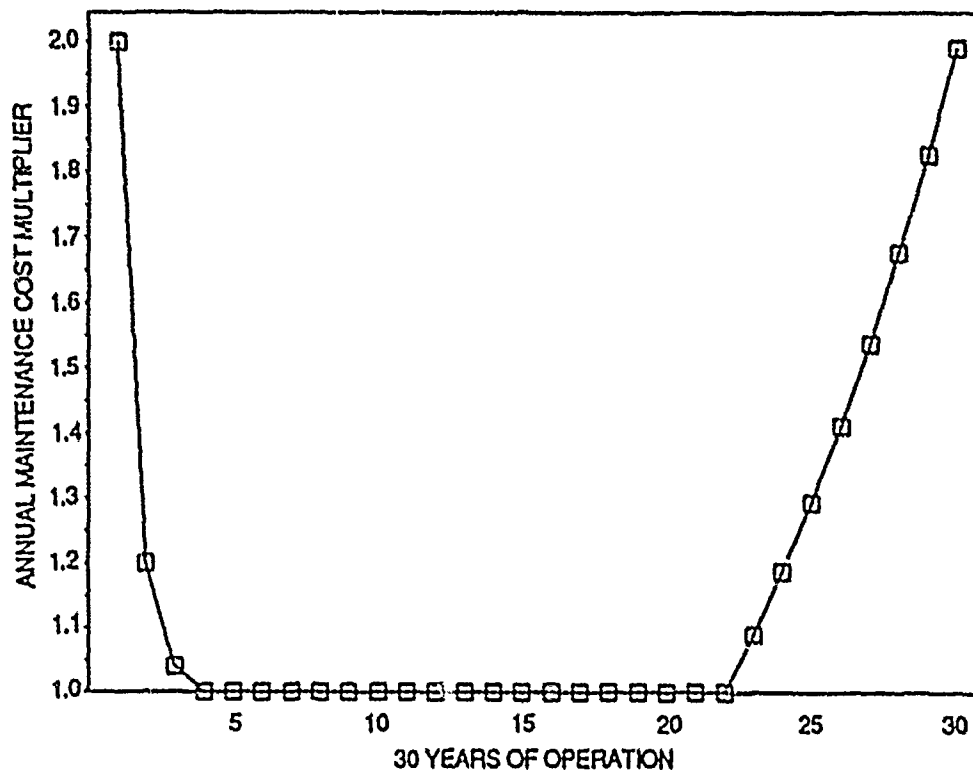


Fig. 5.3. Time-dependent multiplier applied to annual maintenance costs.

5.3.2 Private Financing

For the private-financing scenario, it was assumed that the Air Force will enter into a 31-year contract with a private company to purchase, construct, operate, and maintain the coal-fired boiler equipment. The Air Force will reimburse the contractor directly for their O&M costs and will pay the contractor an annual fee for recovery of their capital investment and profit. Many of the costs associated with private financing are identical to those for Air Force financing. The differences between private and Air Force financing are explained here with the aid of the example discounted cash flow spreadsheet for private financing shown in Table 5.8.

The annual fee in the "CAPITAL COST" line of Table 5.8 is calculated using the standard capital recovery equation over the 30-year economic life of the project with a rate of return on investment that

CASH FLOWS - AS SPENT k\$

[illegible]

will be defined in Sect. 6.1.2. It was also assumed that the contractor incurs O&M costs (including fuel costs) an average of 2 months before it is reimbursed for them. The contractor is paid the same rate of return for these 2 months of working capital. The working capital costs are itemized in the "RETURN ON WORK CAP" line of the cash flow spreadsheet.

A private contractor must pay local taxes, insurance, and federal taxes. These costs are calculated in the cash flow spreadsheet, but they do not affect the "TOTAL COST TO AIR FORCE" line of Table 5.8 because it was assumed that the contractor pays these costs out of their own pocket using their return on investment. Local property taxes and insurance are lumped together, and their annual cost was assumed to be 2% of the capital investment. The federal income tax calculations are based on the following assumptions: (1) capital equipment is depreciated over 15 years using the sum-of-the-years digits (SOYD) method with no salvage value, (2) the tax rate is 34%, and (3) the private contractor is a large company with other sources of income to balance any negative income from this project.

5.3.3 Definitions of Figures-of-Merit

The LCC summary spreadsheet lists the economic results for the existing gas-/oil-fired system plus all 13 coal technologies with either Air Force or private financing. An example LCC summary spreadsheet is shown in Table 5.9. Three different figures-of-merit are presented in the LCC summary spreadsheet: (1) LCC, (2) benefit/cost ratio, and (3) discounted payback period. These figures-of-merit are defined and discussed in this section.

Some of the coal combustion technologies that are examined in this report (such as micronized coal) are not fully commercialized. A word of caution when interpreting the economic results is that the risks and uncertainties of these newer coal technologies have not been penalized in the economic analysis relative to the more established coal technologies (such as stoker coal-firing).

LCC. The LCC of a project is the summation of the discounted annual expenditures over the 30-year economic life of the project. The LCCs shown in Table 5.9 come from the lower right-hand corner of the

Table 5.9. Example LCC summary spreadsheet for Arnold Air Force Station

| ARNOLD AFS: 1 X 72 MBtu/hr, ECONOMIC PARAMETERS = NOMINAL VALUES | | | | | | | | | |
|--|---|------------------|--|--------------------|--------------------|--|--|--------------------|--|
| Total steam output (MBtu/hr) = 72.0 | | | | | | | | | |
| Boiler capacity factor = .720 | | | | | | | | | |
| Number of units for refit = 1 | | | | | | | | | |
| Primary fuel = NATURAL GAS | | | | | | | | | |
| Primary fuel price (constant 1988 \$/MBtu) = 3.97 | | | | | | | | | |
| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | | PRIVATE PROJECT | | |
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/COST RATIO | PAYBACK PERIOD, yr | DISCOUNTED COST, DISCOUNTED AS SPENT k\$ | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/COST RATIO | |
| Natural gas boiler | -- | -- | 45,468 | 1.000 | <--- | Existing system, primary fuel | | | |
| #2 Oil fired boiler | -- | -- | 46,608 | -- | | | | | |
| #6 Oil fired boiler | -- | -- | 0 | -- | | | | | |
| Micronized coal refit | 1 | 23,652 | 21,239 | 2.141 | 3.9 | 23,368 | 1.946 | | |
| Slagging burner refit | 1 | 23,652 | 23,168 | 1.963 | 5.7 | 26,489 | 1.717 | | |
| Modular FBC refit | 1 | 23,951 | 23,600 | 1.927 | 6.2 | 27,334 | 1.663 | | |
| Stoker firing refit | Not applicable because existing boiler was designed for pulverized coal | | | | | | | | |
| Coal/water slurry | 1 | 25,229 | 27,624 | 1.646 | 5.8 | 29,789 | 1.526 | | |
| Coal/oil slurry | Not evaluated | | | | | | | | |
| Low Btu gasifier refit | 2 | 25,348 | 28,215 | 1.612 | 8.3 | 32,101 | 1.416 | | |
| Packaged shell stoker | 2 | 22,633 | 25,101 | 1.811 | 6.4 | 28,476 | 1.597 | | |
| Packaged shell FBC | 2 | 24,897 | 25,226 | 1.802 | 7.1 | 29,303 | 1.552 | | |
| Field erected stoker | 1 | 21,502 | 25,887 | 1.756 | 7.9 | 30,572 | 1.487 | | |
| Field erected FBC | 1 | 23,652 | 26,247 | 1.732 | 8.4 | 31,346 | 1.451 | | |
| Pulverized coal boiler | 1 | 23,075 | 26,716 | 1.702 | 8.9 | 32,080 | 1.417 | | |
| Circulating FBC | 1 | 23,360 | 27,578 | 1.649 | 9.7 | 33,610 | 1.353 | | |

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discounted cash flow spreadsheets. The cash flow spreadsheets are executed numerous times in order to fill Table 5.9. The LCC parameter is calculated for all of the proposed coal-fired systems, as well as the existing gas-/oil-fired system that they would replace. LCCs that have been inflated and discounted over a 30-year period can result in dollar amounts that are difficult to comprehend in absolute terms. It is best if LCCs are used only for relative comparisons between projects.

Benefit/cost ratio. The term "benefit" is used in this report to refer to cost avoidance (i.e., the cost of continued operation of an existing system) rather than cost savings (i.e., the difference between the cost of an existing system and the cost of a new system). The benefit/cost ratio is therefore defined as the LCC of the portion of the existing gas/oil system that would be displaced by coal, divided by the LCC of the proposed new coal system. In the example LCC summary spreadsheet in Table 5.9, the numerators of the benefit/cost ratios are all equal to the LCC of the natural gas boiler, and the denominators depend on the coal technology and financing scenario.

The benefit/cost ratio is the primary figure-of-merit used in this report to interpret the economic results. In general, the use of benefit/cost ratios is not recommended when budget constraints are an important consideration. However, the results in this report are not intended to be used for allocating a fixed budget between competing projects; the purpose instead is to provide guidance for planning Air Force budget requests and/or planning privatized projects. The use of benefit/cost ratios ensures that cost-effective projects are not overlooked just because they are capital intensive.

Three questions can be answered by examining the benefit/cost ratios:

1. What is the best (most economical) coal technology and financing scenario at a particular Air Force base?
2. Which air base has the greatest potential for economical utilization of coal?
3. Will coal be more economical than the existing gas or oil fuels?

The first and second questions involve relative comparisons between two

or more benefit/cost ratios, while the third question depends only on the absolute magnitude of the benefit/cost ratios. In the example in Table 5.9, micronized coal with Air Force financing is the best technology because it has the largest benefit/cost ratio, and it will be more economical than the existing gas system because the ratio is greater than 1.0.

Discounted payback period. This parameter is defined as the time period (measured from the beginning of construction) required for the cumulative savings from a project to pay back the initial investment and other cumulative costs of the project, taking into account the time value of money. During the first few years of a coal-fired boiler project, the cumulative discounted costs of the coal system are generally greater than the cumulative discounted costs of the existing gas/oil system because of the capital costs of the coal equipment. However, coal prices are usually less than gas/oil prices, and the cumulative costs of the coal system tend to increase with time more slowly than the cumulative costs of the gas/oil system. The discounted payback period is defined as the point in time where the cumulative discounted costs of the coal system fall below the cumulative discounted costs of the existing gas/oil system.

The discounted payback period is used in this report only as a secondary figure-of-merit for the following reasons: (1) the discounted payback period has no meaning in the private-financing scenarios where the Air Force does not invest any of their own capital, (2) the discounted payback period will sometimes be undefined because it can be greater than the economic life of the project, and (3) an economic evaluation using discounted payback periods will sometimes be misleading because it completely ignores the economic consequences beyond the payback period.

6. RESULTS OF RANKING STUDY

The cost-estimation and LCC analysis models described in Chap. 5 have been used to examine the economics of coal utilization at 16 Air Force facilities. After some further description concerning input variables and how the results were obtained, the results are presented and a method of ranking the 16 sites is discussed. Some sensitivity analyses to key parameters have been included to help understand the results more thoroughly.

6.1 VALUES OF INPUT VARIABLES

The input parameters for the cost-estimation model and LCC model are defined and described in Chap. 5. The numerical values used in this study for the parameters that vary from site to site are summarized here.

6.1.1 Cost-Estimation Variables

A list of input parameters for the cost model is provided in Table 5.3. Numerical values are given in the table for eight of the parameters. The remaining parameters that are labeled as variables are discussed further in this section.

Important assumptions that define the coal-conversion projects examined in this study are summarized for each Air Force site in Table 6.1. The number of boilers for refit and total output capacity chosen for each project were found through optimization as discussed in Sect. 5.2.1. The expected capacity factor is dependent on this chosen output capacity and the heating load of each boiler plant. Also listed is the need for active SO_2 removal, which has been determined from the sulfur content of available coals (Sect. 4.1) and applicable local environmental regulations (Sect. 4.2). Active SO_2 removal was found to be required at 6 of the 16 sites.

The existing boiler design is also listed in Table 6.1 and was used to determine what boiler modifications are needed for refit technologies and whether derating of a refitted boiler is necessary. Boiler modifications were determined as explained in Sect. 5.1.3, using Tables 5.4 and

Table 6.1. Coal-conversion project definition parameters

| Base | Major command | Existing boiler design fuel | Number of boilers for refit | Total output capacity (MBtu/h) | Expected overall capacity factor (%) | Active SO ₂ removal | Refit boilers derated | Number of technologies considered |
|--------------|---------------|-----------------------------|-----------------------------|--------------------------------|--------------------------------------|--------------------------------|-----------------------|-----------------------------------|
| Elmendorf | AAC | Stoker coal | 2 | 300.0 | 71.9 | Yes | No | 12 |
| Hill | AFLC | No. 2 oil | 3 | 75.0 | 63.5 | Yes | Yes | 7 |
| Kelly | AFLC | No. 2 oil | 1 | 43.5 | 82.4 | No | Yes | 7 |
| Robins | AFLC | Stoker coal | 1 | 54.0 | 80.6 | No | No | 8 |
| Tinker | AFLC | No. 2 oil | 2 | 150.0 | 71.2 | Yes | Yes | 7 |
| Arnold | AFSC | Pulverized coal | 1 | 72.0 | 72.0 | No | No | 11 |
| Hanscom | AFSC | No. 6 oil | 1 | 50.0 | 88.3 | Yes | No | 1 |
| Andrews | MAC | Stoker coal | 1 | 60.0 | 50.4 | No | No | 12 |
| Dover | MAC | Stoker coal | 1 | 50.0 | 58.3 | No | No | 12 |
| McGuire | MAC | Stoker coal | 1 | 50.0 | 61.8 | Yes | No | 12 |
| Scott | MAC | Stoker coal | 1 | 40.0 | 62.6 | Yes | No | 7 |
| Grand Forks | SAC | Stoker coal | 1 | 42.0 | 71.6 | No | No | 12 |
| Minot | SAC | Stoker coal | 1 | 42.0 | 64.6 | No | No | 12 |
| Pease | SAC | No. 6 oil | 1 | 75.0 | 40.7 | No | Yes | 11 |
| Plattsburgh | SAC | No. 6 oil | 1 | 50.0 | 76.4 | No | No | 11 |
| USAF Academy | USAF | No. 5 oil | 1 | 80.0 | 58.0 | No | No | 7 |

5.5 as a guide. Boiler derating was assumed to be necessary at four sites; three were derated simply because they were No. 2 oil-designed units, and the boiler at Pease AFB was assumed to be derated to avoid SO₂ emission regulations (discussed in Sect. 5.2.1). Many details about each individual site are summarized in the Appendix.

The current prices for fuels used in the study are listed in the main tables that summarize the results (Tables 6.3 and 6.5 of Sect. 6.2). Oil and coal/water slurry prices do not vary from site to site, as discussed in Sect. 5.1.3, while natural gas, ROM coal, and stoker coal prices do vary from site to site. One note about coal prices is that the prices used in the analysis for Elmendorf AFB and Pease AFB are optimistic. The coal prices quoted for Elmendorf are from a new company that is not yet in operation. If this new coal is not available in the future, then coal would have to be purchased at a much higher price from the only coal supplier near Elmendorf that is currently in operation. The coal prices quoted for Pease are based on inexpensive rail delivery; however, higher-cost truck delivery may be necessary because the rail connection to Pease is scheduled for removal.

The remaining input variables that have not been defined are the price of electricity and the coal properties (higher heating value, ash content, and sulfur content). Values were determined for these parameters for each of the 16 Air Force sites and can be found in the information summaries in the Appendix.

6.1.2 Economic Variables

Many of the economic assumptions made for the LCC analysis are discussed in Sect. 5.3, and the input parameters to the LCC model are listed in Table 5.6. Four key economic variables are discussed further here because of their potential importance to the study.

General inflation. General inflation, which is a loss in the buying power of money, is an input variable to the LCC model. General inflation is often thought of as being very important in an economic analysis. However, general inflation has no effect on the LCC results for Air Force-financed projects, if the actual discount rate is also inflated to maintain a constant real discount rate. Although inflation

does have a minor effect on the LCC results for privately financed projects, the general inflation rate was assumed to be zero in this study. The effect of this assumption is that all future values in the cash flow spreadsheets will be in constant dollars, as is required by federal guidelines.¹⁰

Discount rate. Federal guidelines specify that a real discount rate of 10% should be used for the evaluation of projects that are not primarily for energy conservation.¹⁰ For most of this study, an actual discount rate of 10% was used, which is equivalent to a real discount rate of 10% because of the assumption of zero general inflation. A 7% discount rate is also examined in Sect. 6.3.2 to determine the sensitivity of the results to the discount rate.

Rate of return on investment. A representative rate of return (ROR) on investment is needed for evaluation of privately financed projects. A before-tax ROR of 17% was selected. Based on the local and federal tax assumptions shown in Table 5.6, this translates to an after-tax ROR of about 12%.

Fuel escalation. Because the results of the LCC analysis were found to be very sensitive to the assumed fuel escalation rates, and because fuel escalation projections are so highly subject to question, three separate fuel escalation scenarios have been examined.

One set of fuel escalators was derived from a DOD memo that gives guidelines for energy-dependent economic analyses.³ The DOD escalators are based directly on the report *Annual Energy Outlook 1986*, published by the Energy Information Administration (EIA) of DOE.⁴ Fuel escalation projections are tabulated in the DOD memo and the 1986 EIA report for distillate oil, residual oil, natural gas, and coal, for both commercial and industrial sectors, in ten different regions of the United States. For the LCC analysis in this report, it was assumed that the industrial fuel escalation rates, averaged over all ten regions of the United States, are applicable. Also, distillate and residual oils were assumed to escalate at the same rate (equal to an average of the escalation rates for distillate and residual oils).

The 1986 study by the EIA includes projections only to the year 2000. The DOD escalation tables were extended to the year 2017 by

assuming that the 1986 EIA escalation projections for the years 1996-2000 (escalation rates for each fuel are constant during this 5-year period) would remain constant through the year 2017. For the LCC analysis in this report, the 30-year economic life ends in the year 2020; therefore, the same escalation rates were assumed to apply all the way to the year 2020. The DOD escalation scenario just described is referred to as the "nominal values" case for fuel escalation. These escalation rates are shown in Table 6.2. For this "nominal values" case, gas and oil prices escalate at rather high rates relative to the price of coal, which will enhance the economic outlook of coal projects.

Table 6.2. Fuel escalation scenarios

| Fuel | Real escalation rate (%/year) | | | |
|------------------------------|----------------------------------|-----------|-----------|--------------------|
| | 1988-1990 | 1990-1995 | 1995-2000 | 2000 and beyond |
| <i>"Nominal values" case</i> | | | | |
| Gas | 3.89 | 8.87 | 5.77 | 5.77 |
| Oil | 4.86 | 7.87 | 4.16 | 4.16 |
| Coal | 1.16 | 2.31 | 1.19 | 1.19 |
| <i>"AEO 1987" case</i> | | | | |
| Gas | 2.28 | 4.70 | 5.49 | 2.75 |
| Oil | 0.17 | 4.16 | 5.55 | 2.77 |
| Coal | 1.46 | 1.76 | 1.61 | 0.81 |
| <i>Zero case</i> | | | | |
| Gas | 0 | 0 | 0 | 0 |
| Oil | 0 | 0 | 0 | 0 |
| Coal | 0 | 0 | 0 | 0 |

A second fuel escalation scenario was developed from the updated *Annual Energy Outlook 1987* report.⁵ Because the updated 1987 report also does not include any escalation projections beyond the year 2000, an author of the report was contacted and asked to recommend the best

assumptions during that time period. The opinion received was that the forces causing high oil and gas price escalation during the 1995-2000 period will weaken significantly in years beyond 2000. To simulate reduced pressure on fuel prices for years beyond 2000, it was assumed that each fuel escalates at one-half the projected rate for the 1995-2000 period. This set of escalators will be referred to as the "AEO 1987" fuel escalators. The precise values used for fuel escalation are given in Table 6.2. The "AEO 1987" escalators lie approximately midway between the "nominal values" escalators and the third escalation scenario of zero fuel escalation.

6.2 RANKING BY BENEFIT/COST RATIO

The 16 Air Force base heating plants have been ranked according to the benefit/cost ratio (see Sect. 5.3.3 for definition). Six economic scenarios were examined: three separate sets of assumptions for fuel escalation were considered, and both Air Force ownership and private ownership were examined. The economic ranking results for the six scenarios are summarized in Tables 6.3 through 6.7. These rankings are discussed in the following sections.

6.2.1 Air Force Financing and Ownership

A summary of the coal-conversion projects examined assuming Air Force ownership is given in Table 6.3. All of the coal combustion technologies that were evaluated at each of the 16 sites are included in the table. The 149 potential coal projects are ranked according to the first column of benefit/cost ratios that were calculated for the "nominal values" of the economic parameters. The list of coal projects for each Air Force site is ordered so that the highest benefit (most attractive) option appears first and the lowest benefit option appears last. The Air Force sites are ordered in Table 6.3 according to the benefit/cost ratios of the best coal technology at each base.

Table 6.4 summarizes the most attractive coal technology at each base for the three fuel escalation scenarios. Micronized coal refit is

| Base (Major commod) | Current fuel and price | Rank | Coal technology | Tech. type | | Coal price (\$/Mbtu) | Benefit/cost ratio | | |
|---------------------------------|------------------------------|------|--------------------|------------|-------|----------------------------|-----------------------------------|---------------------------------------|-----------------------------------|
| | | | | Refit | New | | Parameters = nominal values | Fuel real escalation = AEO 1987 | Fuel real escalation = zero |
| Plattsburgh (SAC) | No. 6 oil \$3.67/Mbtu | 23 | Micronized | X | | 1.97 | 1.562 | 1.281 | 1.011 |
| | | 45 | Slagging | X | | 1.97 | 1.449 | 1.150 | 0.926 |
| | | 48 | Pkg. FBC | | X | 1.97 | 1.431 | 1.172 | 0.923 |
| | | 52 | FBC refit | X | | 1.97 | 1.418 | 1.162 | 0.912 |
| | | 65 | Pkg. stoker | | X | 2.46 | 1.357 | 1.113 | 0.887 |
| | | 91 | Coal/water | X | | 3.00 | 1.293 | 1.062 | 0.859 |
| | | 95 | Field FBC | | X | 1.97 | 1.286 | 1.053 | 0.821 |
| | | 101 | Pulverized | | X | 1.97 | 1.263 | 1.034 | 0.804 |
| | | 107 | Field stoker | | X | 2.46 | 1.248 | 1.023 | 0.808 |
| | | 113 | Circ. FBC | | X | 1.97 | 1.231 | 1.007 | 0.783 |
| 121 | Casifier | X | | 2.46 | 1.196 | 0.981 | 0.781 | | |
| Pease ^a (SAC) | Natural gas \$1.80/Mbtu | 24 | Micronized | X | | 2.07 | 1.540 | 1.196 | 0.917 |
| | | 57 | Slagging | X | | 2.07 | 1.390 | 1.079 | 0.822 |
| | | 61 | Coal/water | X | | 3.00 | 1.369 | 1.066 | 0.834 |
| | | 64 | FBC refit | X | | 2.07 | 1.359 | 1.055 | 0.804 |
| | | 100 | Pkg. FBC | | X | 2.07 | 1.266 | 0.983 | 0.747 |
| | | 110 | Pkg. stoker | | X | 2.56 | 1.245 | 0.968 | 0.744 |
| | | 120 | Field FBC | | X | 2.07 | 1.198 | 0.930 | 0.703 |
| | | 122 | Field stoker | | X | 2.56 | 1.195 | 0.928 | 0.709 |
| | | 129 | Pulverized | | X | 2.07 | 1.170 | 0.908 | 0.686 |
| | | 135 | Circ. FBC | | X | 2.07 | 1.134 | 0.880 | 0.664 |
| 138 | Casifier | X | | 2.56 | 1.110 | 0.863 | 0.663 | | |
| Tinker (AFLC) | Natural gas \$2.85/Mbtu | 28 | Field FBC | | X | 1.68 | 1.532 | 1.151 | 0.840 |
| | | 31 | Pkg. FBC | | X | 1.68 | 1.523 | 1.145 | 0.839 |
| | | 44 | Circ. FBC | | X | 1.68 | 1.451 | 1.090 | 0.793 |
| | | 72 | Pulverized | | X | 1.68 | 1.337 | 1.034 | 0.727 |
| | | 79 | Field stoker | | X | 1.99 | 1.317 | 0.990 | 0.725 |
| | | 89 | Pkg. stoker | | X | 1.99 | 1.298 | 0.976 | 0.717 |
| | | 105 | Coal/water | X | | 3.00 | 1.252 | 0.945 | 0.717 |
| Elmendorf ^b (AAC) | Natural gas \$2.05/Mbtu | 29 | Micronized | X | | 1.63 | 1.527 | 1.146 | 0.851 |
| | | 56 | Slagging | X | | 1.63 | 1.403 | 1.052 | 0.775 |
| | | 59 | FBC refit | X | | 1.63 | 1.379 | 1.034 | 0.762 |
| | | 75 | Field FBC | | X | 1.63 | 1.326 | 0.994 | 0.729 |
| | | 109 | Circ. FBC | | X | 1.63 | 1.247 | 0.934 | 0.681 |
| | | 115 | Pkg. FBC | | X | 1.63 | 1.221 | 0.915 | 0.669 |
| | | 127 | Pulverized | | X | 1.63 | 1.174 | 0.879 | 0.638 |
| | | 141 | Stoker refit | X | | 2.16 | 1.100 | 0.826 | 0.615 |
| | | 145 | Field stoker | | X | 2.16 | 1.064 | 0.798 | 0.590 |
| | | 147 | Coal/water | X | | 3.00 | 1.010 | 0.760 | 0.581 |
| 148 | Pkg. stoker | | X | 2.16 | 0.979 | 0.734 | 0.541 | | |
| 149 | Casifier | X | | 2.16 | 0.849 | 0.636 | 0.468 | | |
| Hill (AFLC) | Natural gas \$2.97/Mbtu | 36 | Pkg. FBC | | X | 1.20 | 1.486 | 1.141 | 0.848 |
| | | 53 | Field FBC | | X | 1.20 | 1.414 | 1.085 | 0.803 |
| | | 71 | Circ. FBC | | X | 1.20 | 1.338 | 1.026 | 0.758 |
| | | 88 | Pkg. stoker | | X | 1.30 | 1.298 | 0.996 | 0.740 |
| | | 103 | Field stoker | | X | 1.30 | 1.260 | 0.967 | 0.716 |
| | | 123 | Pulverized | | X | 1.20 | 1.190 | 0.913 | 0.672 |
| 139 | Coal/water | X | | 1.60 | 1.110 | 0.855 | 0.661 | | |
| Scott (MAC) | Natural gas \$3.90/Mbtu | 39 | Pkg. FBC | | X | 1.24 | 1.473 | 1.141 | 0.854 |
| | | 66 | Pkg. stoker | | X | 1.26 | 1.357 | 1.051 | 0.785 |
| | | 78 | Field FBC | | X | 1.24 | 1.422 | 1.023 | 0.762 |
| | | 93 | Circ. FBC | | X | 1.24 | 1.292 | 1.000 | 0.744 |
| | | 111 | Coal/water | X | | 1.00 | 1.243 | 0.966 | 0.750 |
| | | 114 | Field stoker | | X | 1.26 | 1.231 | 0.952 | 0.709 |
| 134 | Pulverized | | X | 1.24 | 1.141 | 0.882 | 0.654 | | |

Table 6.3 (continued)

| Base (Major command) | Current fuel and price | Rank | Coal technology | Technology type | | Coal price (\$/MBtu) | Benefit/cost ratio | | |
|--|------------------------------|------|--------------------|--------------------|-----|----------------------------|-----------------------------------|---------------------------------------|-----------------------------------|
| | | | | Refit | New | | Parameters = nominal values | Fuel real escalation = AEO 1987 | Fuel real escalation = zero |
| Dover (MAC) | No. 6 oil \$3.67/MBtu | 47 | Micronized | X | | 1.84 | 1.434 | 1.188 | 0.947 |
| | | 77 | Stoker refit | X | | 2.19 | 1.324 | 1.098 | 0.882 |
| | | 83 | Slagging | X | | 1.84 | 1.308 | 1.083 | 0.859 |
| | | 84 | Pkg. FBC | | X | 1.84 | 1.304 | 1.080 | 0.858 |
| | | 92 | Pkg. stoker | | X | 2.19 | 1.292 | 1.071 | 0.860 |
| | | 96 | FBC refit | X | | 1.84 | 1.285 | 1.064 | 0.843 |
| | | 117 | Coal/water | X | | 3.00 | 1.216 | 1.010 | 0.826 |
| | | 130 | Field stoker | | X | 2.19 | 1.164 | 0.964 | 0.767 |
| | | 131 | Field FBC | | X | 1.84 | 1.153 | 0.954 | 0.752 |
| | | 132 | Gasifier | X | | 2.19 | 1.143 | 0.947 | 0.760 |
| | | 137 | Pulverized | | X | 1.84 | 1.127 | 0.932 | 0.733 |
| | | 142 | Circ. FBC | | X | 1.84 | 1.100 | 0.910 | 0.715 |
| Andrews (MAC) | No. 6 oil \$3.67/MBtu | 49 | Micronized | X | | 1.84 | 1.431 | 1.185 | 0.945 |
| | | 80 | Stoker refit | X | | 2.19 | 1.315 | 1.091 | 0.877 |
| | | 90 | Slagging | X | | 1.84 | 1.296 | 1.074 | 0.851 |
| | | 97 | FBC refit | X | | 1.84 | 1.269 | 1.051 | 0.833 |
| | | 118 | Coal/water | X | | 3.00 | 1.211 | 1.006 | 0.823 |
| | | 124 | Pkg. FBC | | X | 1.84 | 1.182 | 0.979 | 0.775 |
| | | 125 | Pkg. stoker | | X | 2.19 | 1.179 | 0.977 | 0.780 |
| | | 133 | Field stoker | | X | 2.19 | 1.142 | 0.946 | 0.752 |
| | | 136 | Field FBC | | X | 1.84 | 1.130 | 0.935 | 0.737 |
| | | 140 | Pulverized | | X | 1.84 | 1.102 | 0.912 | 0.717 |
| | | 144 | Circ. FBC | | X | 1.84 | 1.074 | 0.889 | 0.699 |
| | | 146 | Gasifier | X | | 2.19 | 1.061 | 0.879 | 0.702 |
| USAF Acad. (USAF) | Natural gas \$2.56/MBtu | 70 | Pkg. FBC | | X | 1.17 | 1.339 | 1.038 | 0.784 |
| | | 73 | Pkg. stoker | | X | 1.45 | 1.333 | 1.035 | 0.790 |
| | | 102 | Field stoker | | X | 1.45 | 1.262 | 0.979 | 0.743 |
| | | 106 | Field FBC | | X | 1.17 | 1.252 | 0.970 | 0.729 |
| | | 116 | Pulverized | | X | 1.17 | 1.220 | 0.945 | 0.709 |
| | | 126 | Circ. FBC | | X | 1.17 | 1.179 | 0.913 | 0.685 |
| | | 143 | Coal/water | X | | 3.00 | 1.091 | 0.850 | 0.675 |
| Hanacom (AFSC) | No. 6 oil \$3.67/MBtu | 99 | Coal/water | X | | 3.00 | 1.267 | 1.035 | 0.828 |
| Potential coal use - 20,143 tons/year | | | | | | | | | |

^aLCC results for Pease may be optimistic because of questionable access to inexpensive rail delivery for coal.

^bLCC results for Elmendorf may be optimistic because of questionable availability of inexpensive coal.

Table 6.4. Summary of Air Force-financing results for best coal technologies

| Base | Parameters = nominal values | | | | Fuel escalation = AEO 87 | | | | Fuel escalation = zero | | | |
|------------------------|-----------------------------|--------------------|------|--|--------------------------|--------------------|------|--|------------------------|--------------------|------|--|
| | Best coal technology | Benefit/cost ratio | Rank | | Best coal technology | Benefit/cost ratio | Rank | | Best coal technology | Benefit/cost ratio | Rank | |
| Arnold | Micronized | 2.141 | 1 | | Micronized | 1.616 | 1 | | Micronized | 1.191 | 1 | |
| Kelly | Pkg. stoker | 1.798 | 2 | | Pkg. stoker | 1.369 | 2 | | Pkg. stoker | 1.022 | 3 | |
| Minot | Micronized | 1.743 | 3 | | Micronized | 1.348 | 3 | | Micronized | 1.013 | 4 | |
| Robins | Micronized | 1.737 | 4 | | Micronized | 1.330 | 5 | | Micronized | 1.003 | 6 | |
| McGuire | Micronized | 1.643 | 5 | | Micronized | 1.264 | 7 | | Micronized | 0.950 | 7 | |
| Grand Forks | Micronized | 1.632 | 6 | | Micronized | 1.345 | 4 | | Micronized | 1.057 | 2 | |
| Plattsburgh | Micronized | 1.562 | 7 | | Micronized | 1.281 | 6 | | Micronized | 1.011 | 5 | |
| Pease ^a | Micronized | 1.540 | 8 | | Micronized | 1.196 | 8 | | Micronized | 0.917 | 10 | |
| Tinker | Field FBC | 1.532 | 9 | | Field FBC | 1.151 | 11 | | Field FBC | 0.840 | 14 | |
| Elmendorf ^b | Micronized | 1.527 | 10 | | Micronized | 1.146 | 12 | | Micronized | 0.851 | 12 | |
| Hill | Pkg. FBC | 1.486 | 11 | | Pkg. FBC | 1.141 | 14 | | Pkg. FBC | 0.848 | 13 | |
| Scott | Pkg. FBC | 1.473 | 12 | | Pkg. FBC | 1.141 | 13 | | Pkg. FBC | 0.854 | 11 | |
| Dover | Micronized | 1.434 | 13 | | Micronized | 1.188 | 9 | | Micronized | 0.947 | 8 | |
| Andrews | Micronized | 1.431 | 14 | | Micronized | 1.185 | 10 | | Micronized | 0.945 | 9 | |
| USAF Academy | Pkg. FBC | 1.339 | 15 | | Pkg. FBC | 1.038 | 15 | | Pkg. stoker | 0.790 | 16 | |
| Hanscom | Coal/water | 1.267 | 16 | | Coal/water | 1.035 | 16 | | Coal/water | 0.828 | 15 | |

^aLCC results for Pease may be optimistic because of questionable access to inexpensive rail delivery for coal.

^bLCC results for Elmendorf may be optimistic because of questionable availability of inexpensive coal.

the lowest-cost option at most of the bases (10 of 16). At the remaining six bases (Kelly, Tinker, Hill, Scott, USAF Academy, and Hanscom), micronized coal and the other dry coal refit technologies were not evaluated because of space limitations inside and near the existing heating plants. The lowest-cost options at these six bases are either coal/water slurry refit or one of the replacement boiler technologies.

It is observed from Table 6.4 that Arnold is ranked first in each case. The sites ranked 2 through 7 include Kelly, Minot, Robins, McGuire, Grand Forks, and Plattsburgh in each case, although the respective order changes. Beyond the top seven sites, it is somewhat more difficult to generalize.

The most basic issue that needs to be addressed is whether coal will be more economical than the existing gas or oil fuels. The results in Table 6.4 indicate that the answer to this question depends strongly on the fuel escalation assumptions. For the "nominal values" case of fuel escalation, coal appears to be a good choice at all of the bases because all of the benefit/cost ratios are significantly >1.0 . For the zero fuel escalation case, most of the bases have benefit/cost ratios that are <1.0 , and at the bases that do have benefit/cost ratios >1.0 , the savings in gas or oil costs may not be significant enough to justify conversion to coal.

6.2.2 Private Financing and Ownership

The same type of analysis presented above for the Air Force-ownership cases is repeated here for the private-ownership scenarios. Tables 6.5 and 6.6 summarize these results. It was found that the ranking of the sites is very similar to the previously discussed Air Force-ownership cases. Again, it is observed that Arnold is ranked first in each case. The sites ranked 2 through 7 include Kelly, Robins, Minot, McGuire, Grand Forks, and Plattsburgh.

When the private-financing results in Table 6.6 are compared to the Air Force-financing results in Table 6.4, it appears that Air Force financing is more attractive because the benefit/cost ratios are all slightly greater than those for private financing. This conclusion is contrary to the common belief that a private company can work less

Table 6.5. Private-financing results with ranking according to "nominal values"

| Base (Major command) | Current fuel and price | Rank | Coal technology | Technology type | | Coal price (\$/Mtu) | Benefit/cost ratio | | |
|--|------------------------------|--------------|--------------------|--------------------|-------|---------------------------|-----------------------------------|---------------------------------------|-----------------------------------|
| | | | | Refit | New | | Parameters = nominal values | Fuel real escalation = AEO 1987 | Fuel real escalation = zero |
| Arnold (AFSC) | Natural gas \$3.97/Mtu | 1 | Micronized | X | | 1.75 | 1.946 | 1.468 | 1.077 |
| | | 2 | Slagging | X | | 1.75 | 1.717 | 1.294 | 0.942 |
| | | 3 | FBC refit | X | | 1.75 | 1.663 | 1.254 | 0.912 |
| | | 5 | Pkg. stoker | | X | 1.97 | 1.597 | 1.284 | 0.882 |
| | | 8 | Pkg. FBC | | X | 1.75 | 1.552 | 1.169 | 0.849 |
| | | 10 | Coal/water | X | | 3.00 | 1.526 | 1.155 | 0.872 |
| | | 11 | Field stoker | | X | 1.97 | 1.487 | 1.121 | 0.815 |
| | | 14 | Field FBC | | X | 1.75 | 1.491 | 1.092 | 0.788 |
| | | 17 | Pulverized | | X | 1.75 | 1.417 | 1.067 | 0.768 |
| | | 18 | Gasifier | X | | 1.97 | 1.416 | 1.068 | 0.782 |
| Potential coal use = 23,652 tons/year | 25 | Circ. FBC | | X | 1.75 | 1.353 | 1.038 | 0.732 | |
| Kelly (AFPLC) | Natural gas \$4.00/Mtu | 4 | Pkg. stoker | | X | 1.98 | 1.604 | 1.223 | 0.909 |
| | | 9 | Pkg. FBC | | X | 1.87 | 1.545 | 1.175 | 0.868 |
| | | 16 | Coal/water | X | | 3.00 | 1.419 | 1.082 | 0.822 |
| | | 20 | Field stoker | | X | 1.98 | 1.398 | 1.063 | 0.781 |
| | | 27 | Field FBC | | X | 1.87 | 1.339 | 1.017 | 0.744 |
| | | 32 | Pulverized | | X | 1.87 | 1.306 | 0.992 | 0.724 |
| Potential coal use = 16,014 tons/year | 45 | Circ. FBC | | X | 1.87 | 1.264 | 0.960 | 0.700 | |
| Robins (AFPLC) | Natural gas \$3.19/Mtu | 4 | Micronized | X | | 1.77 | 1.566 | 1.213 | 0.911 |
| | | 35 | Pkg. stoker | | X | 1.99 | 1.294 | 0.989 | 0.741 |
| | | 43 | Pkg. FBC | | X | 1.77 | 1.274 | 0.974 | 0.724 |
| | | 47 | Coal/water | X | | 3.00 | 1.262 | 0.968 | 0.748 |
| | | 57 | Field stoker | | X | 1.99 | 1.213 | 0.927 | 0.690 |
| | | 63 | Field FBC | | X | 1.77 | 1.186 | 0.906 | 0.669 |
| Potential coal use = 17,268 tons/year | 70 | Pulverized | | X | 1.77 | 1.157 | 0.883 | 0.651 | |
| 89 | Circ. FBC | | X | 1.77 | 1.114 | 0.850 | 0.626 | | |
| Hinsat (SAC) | Natural gas \$3.60/Mtu | 7 | Micronized | X | | 1.48 | 1.567 | 1.211 | 0.912 |
| | | 19 | Stoker refit | X | | 1.87 | 1.398 | 1.082 | 0.821 |
| | | 23 | Slagging | X | | 1.48 | 1.360 | 1.050 | 0.786 |
| | | 24 | Pkg. FBC | | X | 1.48 | 1.353 | 1.045 | 0.784 |
| | | 26 | Pkg. stoker | | X | 1.87 | 1.349 | 1.043 | 0.790 |
| | | 31 | FBC refit | X | | 1.48 | 1.308 | 1.011 | 0.756 |
| | | 50 | Coal/water | X | | 3.00 | 1.249 | 0.969 | 0.754 |
| | | 52 | Gasifier | X | | 1.87 | 1.247 | 0.965 | 0.732 |
| | | 78 | Flow stoker | | X | 1.87 | 1.141 | 0.882 | 0.661 |
| | | 81 | Field FBC | | X | 1.48 | 1.131 | 0.873 | 0.649 |
| Potential coal use = 12,176 tons/year | 95 | Pulverized | | X | 1.48 | 1.093 | 0.844 | 0.626 | |
| 107 | Circ. FBC | | X | 1.48 | 1.065 | 0.822 | 0.610 | | |
| McGuire (MAC) | Natural gas \$4.00/Mtu | 12 | Micronized | X | | 1.89 | 1.482 | 1.140 | 0.854 |
| | | 29 | Pkg. FBC | | X | 1.89 | 1.314 | 1.010 | 0.754 |
| | | 30 | Slagging | X | | 1.89 | 1.314 | 1.009 | 0.752 |
| | | 36 | Coal/water | X | | 3.00 | 1.290 | 0.994 | 0.763 |
| | | 40 | FBC refit | X | | 1.89 | 1.285 | 0.987 | 0.735 |
| | | 66 | Stoker refit | X | | 2.25 | 1.175 | 0.903 | 0.677 |
| | | 76 | Field FBC | | X | 1.89 | 1.143 | 0.878 | 0.650 |
| | | 77 | Pkg. stoker | | X | 2.25 | 1.143 | 0.879 | 0.658 |
| | | 96 | Gasifier | X | | 2.25 | 1.092 | 0.840 | 0.631 |
| | | 101 | Circ. FBC | | X | 1.89 | 1.081 | 0.830 | 0.613 |
| Potential coal use = 13,217 tons/year | 121 | Field stoker | | X | 2.25 | 1.010 | 0.776 | 0.576 | |
| 131 | Pulverized | | X | 1.89 | 0.974 | 0.748 | 0.551 | | |
| Grand Forks (SAC) | No. 6 oil \$3.67/Mtu | 13 | Micronized | X | | 1.48 | 1.474 | 1.213 | 0.951 |
| | | 28 | Stoker refit | X | | 1.87 | 1.319 | 1.087 | 0.859 |
| | | 38 | Slagging | X | | 1.48 | 1.288 | 1.059 | 0.825 |
| | | 41 | Pkg. FBC | | X | 1.48 | 1.285 | 1.057 | 0.825 |
| | | 42 | Pkg. stoker | | X | 1.87 | 1.274 | 1.050 | 0.829 |
| | | 53 | FBC refit | X | | 1.48 | 1.245 | 1.025 | 0.797 |
| | | 68 | Coal/water | X | | 3.00 | 1.162 | 0.960 | 0.778 |
| | | 73 | Gasifier | X | | 1.87 | 1.149 | 0.947 | 0.747 |
| | | 97 | Field stoker | | X | 1.87 | 1.089 | 0.896 | 0.709 |
| | | 100 | Field FBC | | X | 1.48 | 1.083 | 0.890 | 0.689 |
| Potential coal use = 13,495 tons/year | 110 | Pulverized | | X | 1.48 | 1.049 | 0.863 | 0.666 | |
| 119 | Circ. FBC | | X | 1.48 | 1.018 | 0.836 | 0.646 | | |

Table 1.3 (continued)

| Base (Major company) | Current fuel and price | Rank | Coal technology | Technology | | Coal price (\$/MBtu) | Benefit/cost ratio | | | | |
|--|------------------------------|---|--------------------|--------------|--------------|----------------------------|-----------------------------------|---------------------------------------|-----------------------------------|-------|-------|
| | | | | Refit | New | | Parameters = nominal values | Fuel real escalation = AEO 1987 | Fuel real escalation = zero | | |
| Plattsburgh (SAC) | No. 6 oil \$1.67/MBtu | 15 | Micronized | X | | 1.97 | 1.425 | 1.168 | 0.918 | | |
| | | 44 | Slagging | X | | 1.97 | 1.266 | 1.037 | 0.809 | | |
| | | 48 | Pkg. FBC | | X | 1.97 | 1.247 | 1.029 | 0.806 | | |
| | | 54 | FBC refit | X | | 1.97 | 1.212 | 1.009 | 0.787 | | |
| | | 56 | Pkg. stoker | | X | 2.46 | 1.222 | 1.032 | 0.794 | | |
| | | 61 | Coal/water | X | | 1.97 | 1.192 | 0.979 | 0.787 | | |
| | | 98 | Field FBC | | X | 1.97 | 1.086 | 0.859 | 0.688 | | |
| | | 101 | Gasifier | X | | 2.46 | 1.074 | 0.881 | 0.697 | | |
| | | 105 | Field stoker | | X | 2.46 | 1.071 | 0.877 | 0.687 | | |
| | | 103 | Pulverized | | X | 1.97 | 1.061 | 0.868 | 0.671 | | |
| Potential coal use = 16,339 tons/year | | 116 | Circ. FBC | | X | 1.97 | 1.021 | 0.835 | 0.645 | | |
| Elmendorf ^a (AAC) | Natural gas \$2.05/MBtu | 21 | Micronized | X | | 1.63 | 1.386 | 1.039 | 0.767 | | |
| | | 55 | Slagging | X | | 1.63 | 1.228 | 0.920 | 0.672 | | |
| | | 61 | FBC refit | X | | 1.63 | 1.191 | 0.892 | 0.651 | | |
| | | 84 | Field FBC | | X | 1.63 | 1.124 | 0.842 | 0.611 | | |
| | | 113 | Circ. FBC | | X | 1.63 | 1.031 | 0.771 | 0.556 | | |
| | | 114 | Pkg. FBC | | X | 1.63 | 1.030 | 0.771 | 0.558 | | |
| | | 128 | Stoker refit | X | | 2.16 | 0.903 | 0.737 | 0.545 | | |
| | | 129 | Pulverized | | X | 1.61 | 0.981 | 0.733 | 0.528 | | |
| | | 137 | Coal/water | X | | 3.00 | 0.941 | 0.708 | 0.539 | | |
| | | Potential coal use = 154,374 tons/year | | 143 | Field stoker | | X | 2.16 | 0.915 | 0.686 | 0.501 |
| | 148 | Pkg. stoker | | X | 2.16 | 0.842 | 0.631 | 0.460 | | | |
| | 149 | Gasifier | X | | 2.16 | 0.760 | 0.534 | 0.404 | | | |
| Pease ^b (SAC) | Natural gas \$1.83/MBtu | 22 | Micronized | X | | 2.07 | 1.384 | 1.075 | 0.820 | | |
| | | 51 | Coal/water | X | | 1.00 | 1.249 | 0.972 | 0.757 | | |
| | | 58 | Slagging | X | | 2.07 | 1.196 | 0.928 | 0.703 | | |
| | | 71 | FBC refit | X | | 2.07 | 1.153 | 0.895 | 0.677 | | |
| | | 99 | Pkg. stoker | | X | 2.56 | 1.083 | 0.842 | 0.643 | | |
| | | 106 | Pkg. FBC | | X | 2.07 | 1.071 | 0.831 | 0.628 | | |
| | | 124 | Field stoker | | X | 2.56 | 0.996 | 0.773 | 0.586 | | |
| | | 127 | Field FBC | | X | 2.07 | 0.984 | 0.763 | 0.573 | | |
| | | 133 | Gasifier | X | | 2.56 | 0.963 | 0.748 | 0.571 | | |
| | | Potential coal use = 13,057 tons/year | | 135 | Pulverized | | X | 2.07 | 0.956 | 0.741 | 0.556 |
| | 144 | Circ. FBC | | X | 2.07 | 0.911 | 0.706 | 0.529 | | | |
| Tinker (APLC) | Natural gas \$2.85/MBtu | 53 | Pkg. FBC | X | | 1.65 | 1.334 | 0.979 | 0.711 | | |
| | | 57 | Field FBC | | X | 1.68 | 1.288 | 0.967 | 0.700 | | |
| | | 59 | Circ. FBC | | X | 1.68 | 1.192 | 0.895 | 0.644 | | |
| | | 74 | Coal/water | X | | 3.00 | 1.148 | 0.866 | 0.653 | | |
| | | 83 | Pkg. stoker | | X | 1.99 | 1.124 | 0.845 | 0.616 | | |
| | | 88 | Field stoker | | X | 1.99 | 1.116 | 0.838 | 0.608 | | |
| | | 93 | Pulverized | | X | 1.69 | 1.111 | 0.833 | 0.598 | | |
| Cover (SAC) | No. 6 oil \$1.67/MBtu | 54 | Micronized | X | | 1.84 | 1.295 | 1.073 | 0.851 | | |
| | | 62 | Stoker refit | X | | 2.19 | 1.188 | 0.985 | 0.788 | | |
| | | 75 | Pkg. stoker | | X | 2.19 | 1.148 | 0.951 | 0.759 | | |
| | | 80 | Slagging | X | | 1.84 | 1.135 | 0.939 | 0.741 | | |
| | | 82 | Pkg. FBC | | X | 1.84 | 1.129 | 0.935 | 0.739 | | |
| | | 87 | Coal/water | X | | 1.84 | 1.117 | 0.928 | 0.755 | | |
| | | 94 | FBC refit | X | | 1.84 | 1.100 | 0.910 | 0.717 | | |
| | | 120 | Gasifier | X | | 2.19 | 1.012 | 0.838 | 0.669 | | |
| | | Potential coal use = 12,468 tons/year | | 130 | Field stoker | | X | 2.19 | 0.980 | 0.811 | 0.641 |
| | | | 134 | Field FBC | | X | 1.84 | 0.960 | 0.793 | 0.622 | |
| | 140 | Pulverized | | X | 1.84 | 0.933 | 0.771 | 0.603 | | | |
| | 146 | Circ. FBC | | X | 1.84 | 0.898 | 0.742 | 0.580 | | | |
| Andrews (IAC) | No. 6 oil \$1.67/MBtu | 59 | Micronized | X | | 1.84 | 1.287 | 1.066 | 0.846 | | |
| | | 64 | Stoker refit | X | | 2.19 | 1.176 | 0.975 | 0.779 | | |
| | | 76 | Slagging | X | | 1.84 | 1.118 | 0.925 | 0.730 | | |
| | | 91 | Coal/water | X | | 3.00 | 1.108 | 0.920 | 0.749 | | |
| | | Potential coal use = 12,935 tons/year | | 102 | FBC refit | X | | 1.84 | 1.079 | 0.893 | 0.704 |
| | | | 115 | Pkg. stoker | | X | 2.19 | 1.026 | 0.849 | 0.674 | |
| | | | 122 | Pkg. FBC | | X | 1.84 | 1.003 | 0.830 | 0.653 | |
| | | | 136 | Field stoker | | X | 2.19 | 0.956 | 0.790 | 0.623 | |
| | | | 141 | Field FBC | | X | 1.84 | 0.932 | 0.771 | 0.604 | |
| | | | 142 | Gasifier | X | | 2.19 | 0.920 | 0.762 | 0.605 | |
| | 145 | Pulverized | | X | 1.84 | 0.905 | 0.749 | 0.585 | | | |
| | 147 | Circ. FBC | | X | 1.84 | 0.869 | 0.718 | 0.561 | | | |

Table 6.5 (continued)

| Base (Major command) | Current fuel and price | Rank | Coal technology | Technology type | | Coal price (\$/Mtu) | Benefit/coal ratio | | |
|--|------------------------------|------|--------------------|--------------------|-----|---------------------------|-----------------------------------|---------------------------------------|-----------------------------------|
| | | | | Refit | Rev | | Parameters = nominal values | Fuel real escalation = AEO 1987 | Fuel real escalation = zero |
| Scott (MAC) | Natural gas \$1.80/MMBtu | 46 | Pkg. FBC | | X | 1.24 | 1.263 | 0.978 | 0.729 |
| | | 65 | Pkg. stoker | | X | 1.26 | 1.176 | 0.910 | 0.678 |
| | | 79 | Coal/water | X | | 3.00 | 1.135 | 0.882 | 0.681 |
| | | 94 | Field FBC | | X | 1.24 | 1.097 | 0.849 | 0.639 |
| | | 104 | Circ. FBC | | X | 1.24 | 1.050 | 0.812 | 0.602 |
| Potential coal use = 13,731 tons/year | | 117 | Field stoker | | X | 1.26 | 1.020 | 0.789 | 0.585 |
| | | 118 | Pulverized | | X | 1.24 | 0.918 | 0.726 | 0.536 |
| | | | | | | | | | |
| Hill (AFPC) | Natural gas \$2.97/MMBtu | 49 | Pkg. FBC | | X | 1.20 | 1.252 | 0.961 | 0.710 |
| | | 69 | Field FBC | | X | 1.20 | 1.159 | 0.889 | 0.654 |
| | | 92 | Pkg. stoker | | X | 1.30 | 1.104 | 0.847 | 0.626 |
| | | 104 | Circ. FBC | | X | 1.20 | 1.071 | 0.823 | 0.604 |
| | | 112 | Field stoker | | X | 1.30 | 1.037 | 0.795 | 0.585 |
| Potential coal use = 23,560 tons/year | | 125 | Coal/water | X | | 3.00 | 0.994 | 0.766 | 0.588 |
| | | 132 | Pulverized | | X | 1.20 | 0.968 | 0.742 | 0.543 |
| Hanscom (AFSC) | No. 6 oil \$3.67/MMBtu | 67 | Coal/water | X | | 3.00 | 1.165 | 0.954 | 0.760 |
| Potential coal use = 20,141 tons/year | | | | | | | | | |
| USAF Acad. (USAF) | Natural gas \$2.56/MMBtu | 72 | Pkg. stoker | | X | 1.45 | 1.152 | 0.894 | 0.678 |
| | | 85 | Pkg. FBC | | X | 1.17 | 1.124 | 0.871 | 0.654 |
| | | 111 | Field stoker | | X | 1.45 | 1.040 | 0.806 | 0.603 |
| | | 118 | Field FBC | | X | 1.17 | 1.013 | 0.788 | 0.589 |
| Potential coal use = 24,310 tons/year | | 123 | Coal/water | X | | 3.00 | 0.998 | 0.777 | 0.613 |
| | | 126 | Pulverized | | X | 1.17 | 0.987 | 0.764 | 0.570 |
| | | 139 | Circ. FBC | | X | 1.17 | 0.936 | 0.725 | 0.540 |

^aLCC results for Elmendorf may be optimistic because of questionable availability of inexpensive coal.

^bLCC results for Pease may be optimistic because of questionable access to inexpensive rail delivery for coal.

expensively than the government. In the LCC analysis, the private-financing scenarios were not given any special treatment. Because of a lack of better information, it was assumed that a private company would have to invest the same amount of capital as the Air Force and incur the same O&M costs. Private financing is therefore more expensive because the private company must also be paid a profit.

6.2.3 Overall Observations

Some meaningful observations can be made by examining the results for all six of the economic scenarios in Table 6.7. The top candidate for coal utilization is Arnold. Kelly, Grand Forks, Minot, Robins, Plattsburgh, and McGuire are ranked 2 through 7 for all six scenarios. Certain sites that do not appear above a ranking of 11 for any case include the USAF Academy, Hanscom, Hill, and Scott.

Table 6.6. Summary of private-financing results for best coal technologies

| Base | Parameters = nominal values | | | Fuel escalation = AEO 87 | | | Fuel escalation = zero | | |
|------------------------|-----------------------------|--------------------|------|--------------------------|--------------------|------|------------------------|--------------------|------|
| | Best coal technology | Benefit/cost ratio | Rank | Best coal technology | Benefit/cost ratio | Rank | Best coal technology | Benefit/cost ratio | Rank |
| Arnold | Micronized | 1.946 | 1 | Micronized | 1.468 | 1 | Micronized | 1.077 | 1 |
| Kelly | Pkg. stoker | 1.608 | 2 | Pkg. stoker | 1.223 | 2 | Pkg. stoker | 0.909 | 6 |
| Kobins | Micronized | 1.586 | 3 | Micronized | 1.213 | 4 | Micronized | 0.911 | 5 |
| Minot | Micronized | 1.567 | 4 | Micronized | 1.211 | 5 | Micronized | 0.912 | 4 |
| McGuire | Micronized | 1.482 | 5 | Micronized | 1.140 | 7 | Micronized | 0.854 | 7 |
| Grand Forks | Micronized | 1.474 | 6 | Micronized | 1.213 | 3 | Micronized | 0.951 | 2 |
| Plattsburgh | Micronized | 1.425 | 7 | Micronized | 1.168 | 6 | Micronized | 0.918 | 3 |
| Elmendorf ^a | Micronized | 1.386 | 8 | Micronized | 1.039 | 11 | Micronized | 0.767 | 11 |
| Pease ^b | Micronized | 1.384 | 9 | Micronized | 1.075 | 8 | Micronized | 0.820 | 10 |
| Tinker | Pkg. FBC | 1.304 | 10 | Pkg. FBC | 0.979 | 12 | Pkg. FBC | 0.711 | 14 |
| Dover | Micronized | 1.295 | 11 | Micronized | 1.073 | 9 | Micronized | 0.851 | 8 |
| Andrews | Micronized | 1.287 | 12 | Micronized | 1.066 | 10 | Micronized | 0.846 | 9 |
| Scott | Pkg. FBC | 1.263 | 13 | Pkg. FBC | 0.978 | 13 | Pkg. FBC | 0.729 | 13 |
| Hill | Pkg. FBC | 1.252 | 14 | Pkg. FBC | 0.961 | 14 | Pkg. FBC | 0.710 | 15 |
| Hanscom | Coal/water | 1.168 | 15 | Coal/water | 0.954 | 15 | Coal/water | 0.760 | 12 |
| USAF Academy | Pkg. stoker | 1.152 | 16 | Pkg. stoker | 0.894 | 16 | Pkg. stoker | 0.678 | 16 |

^aLCC results for Elmendorf may be optimistic because of questionable availability of inexpensive coal.

^bLCC results for Pease may be optimistic because of questionable access to inexpensive rail delivery for coal.

Table 6.7. Summary of ranking results for Air Force and private financing

| Base | Rank for Air Force financing | | | Rank for private financing | | | Average rank |
|------------------------|------------------------------|-----|------|----------------------------|-----|------|--------------|
| | Nominal | AEO | Zero | Nominal | AEO | Zero | |
| Arnold | 1 | 1 | 1 | 1 | 1 | 1 | 1.0 |
| Kelly | 2 | 2 | 3 | 2 | 2 | 6 | 2.8 |
| Grand Forks | 6 | 4 | 2 | 6 | 3 | 2 | 3.8 |
| Minot | 3 | 3 | 4 | 4 | 5 | 4 | 3.8 |
| Robins | 4 | 5 | 6 | 3 | 4 | 5 | 4.5 |
| Plattsburgh | 7 | 6 | 5 | 7 | 6 | 3 | 5.7 |
| McGuire | 5 | 7 | 7 | 5 | 7 | 7 | 6.3 |
| Pease ^a | 8 | 8 | 10 | 9 | 8 | 10 | 8.8 |
| Dover | 13 | 9 | 8 | 11 | 9 | 8 | 9.7 |
| Andrews | 14 | 10 | 9 | 12 | 10 | 9 | 10.7 |
| Elmendorf ^b | 10 | 12 | 12 | 8 | 11 | 11 | 10.7 |
| Tinker | 9 | 11 | 14 | 10 | 12 | 14 | 11.7 |
| Scott | 12 | 13 | 11 | 13 | 13 | 13 | 12.5 |
| Hill | 11 | 14 | 13 | 14 | 14 | 15 | 13.5 |
| Hanscom | 16 | 16 | 15 | 15 | 15 | 12 | 14.8 |
| USAF Academy | 15 | 15 | 16 | 16 | 16 | 16 | 15.7 |

^aLCC results for Pease may be optimistic because of questionable access to inexpensive rail delivery for coal.

^bLCC results for Elmendorf may be optimistic because of questionable availability of inexpensive coal.

The process of ranking the Air Force sites in the manner described above is simple from a mathematical viewpoint. However, all economic analyses should be viewed with skepticism because of the uncertainty associated with predicting future events. An appropriate level of skepticism is especially important when interpreting the results of this study because the recent trend of unstable energy prices will probably continue into the future. The results of the LCC analysis should therefore be used only to identify general trends, while small differences should be considered insignificant.

6.3 SENSITIVITY TO SELECTED ECONOMIC ASSUMPTIONS

The sensitivity of the results to some important economic assumptions has been examined. The effect of fuel escalation has already been examined in the main body of results. Other important parameters to be examined in this section include the discounted payback period and the effect of discount rate.

It was found that reasonable variations in the assumed values of key economic parameters can have significant effects on the absolute magnitudes of the benefit/cost ratios (or other measures of economic benefit). However, these parametric variations generally do not have a significant effect on the ranking or ordering of the Air Force sites examined in this study.

6.3.1 Ranking by Discounted Payback Period

The discounted payback period is used in this study only as a secondary figure-of-merit for the reasons discussed in Sect. 5.3.3. Discounted payback periods were calculated for all Air Force-financed projects, and selected results are summarized in Table 6.8 for the top 12 Air Force sites from Table 6.7. The discounted payback periods follow the same trends as the benefit/cost ratios (i.e., the projects with the highest benefit/cost ratios tend to have the shortest payback periods), although there are some minor differences. The use of discounted payback periods for comparisons will tend to favor coal-conversion projects that are less capital intensive.

The answer to the question of whether coal will be a more attractive fuel than gas or oil is again strongly influenced by the fuel escalation assumptions. For the "nominal values" escalation case, most of the coal-conversion projects have discounted payback periods that are <10 years. For zero fuel escalation, the payback periods for most of the projects are greater than the economic life of the projects. The notable exception for zero fuel escalation is the micronized coal refit option at Arnold, which has a payback period <10 years.

Table 6.8. Discounted payback periods for selected Air Force-financed projects

| Base (Major command) | Coal technology | Technology type | | Parameters - nominal values | | Fuel escalation = AFO 1987 | | Fuel escalation = zero | |
|---------------------------------|--------------------|--------------------|-----|--------------------------------|----------------------------------|-------------------------------|----------------------------------|---------------------------|----------------------------------|
| | | Refit | New | Benefit/cost ratio | Discounted payback (years) | Benefit/cost ratio | Discounted payback (years) | Benefit/cost ratio | Discounted payback (years) |
| Arnold (AFSC) | Micronized | X | | 2.141 | 3.9 | 1.616 | 4.7 | 1.191 | 6.4 |
| | Slagging | X | | 1.963 | 5.7 | 1.480 | 7.3 | 1.085 | 12.8 |
| | FBC refit | X | | 1.927 | 6.2 | 1.453 | 8.0 | 1.064 | 15.2 |
| | Pkg. stoker | | X | 1.811 | 6.4 | 1.367 | 8.6 | 1.008 | 25.2 |
| Kelly (AFLC) | Pkg. stoker | | X | 1.798 | 5.9 | 1.369 | 7.9 | 1.022 | 19.3 |
| | Pkg. FBC | | X | 1.760 | 6.8 | 1.339 | 9.2 | 0.995 | >31 |
| Grand Forks (SAC) | Micronized | X | | 1.632 | 5.4 | 1.345 | 7.8 | 1.057 | 12.9 |
| | Slagging | X | | 1.485 | 8.1 | 1.223 | 12.3 | 0.957 | >31 |
| | Pkg. FBC | | X | 1.483 | 8.1 | 1.221 | 12.3 | 0.958 | >31 |
| | Stoker refit | X | | 1.469 | 7.1 | 1.211 | 11.3 | 0.962 | >31 |
| Minot (SAC) | Micronized | X | | 1.743 | 6.0 | 1.348 | 8.0 | 1.013 | 19.8 |
| | Slagging | X | | 1.577 | 8.9 | 1.219 | 12.6 | 0.917 | >31 |
| | Pkg. FBC | | X | 1.570 | 9.0 | 1.214 | 12.8 | 0.915 | >31 |
| | Stoker refit | X | | 1.564 | 7.9 | 1.210 | 11.5 | 0.923 | >31 |
| Robins (AFLC) | Micronized | X | | 1.737 | 5.6 | 1.330 | 7.7 | 1.003 | 26.0 |
| | Pkg. FBC | | X | 1.470 | 10.6 | 1.124 | 16.8 | 0.842 | >31 |
| | Pkg. stoker | | X | 1.463 | 10.0 | 1.119 | 16.5 | 0.844 | >31 |
| Flattsburgh (SAC) | Micronized | X | | 1.562 | 5.6 | 1.281 | 8.7 | 1.011 | 21.3 |
| | Slagging | X | | 1.440 | 8.3 | 1.180 | 13.4 | 0.926 | >31 |
| | Pkg. FBC | | X | 1.431 | 8.5 | 1.172 | 13.8 | 0.923 | >31 |
| McGuire (MAC) | Micronized | X | | 1.643 | 6.8 | 1.264 | 9.7 | 0.950 | >31 |
| | Pkg. FBC | | X | 1.513 | 9.7 | 1.163 | 14.6 | 0.873 | >31 |
| Pease ^a (SAC) | Micronized | X | | 1.540 | 7.9 | 1.196 | 11.7 | 0.917 | >31 |
| | Slagging | X | | 1.390 | 12.0 | 1.079 | 19.9 | 0.822 | >31 |
| | Coal/water | X | | 1.569 | 10.4 | 1.066 | 19.4 | 0.834 | >31 |
| | FBC refit | X | | 1.359 | 13.1 | 1.055 | 22.6 | 0.804 | >31 |
| | Pkg. FBC | | X | 1.266 | 15.8 | 0.983 | >31 | 0.747 | >31 |
| Dover (MAC) | Micronized | X | | 1.434 | 7.3 | 1.188 | 11.8 | 0.947 | >31 |
| | Stoker refit | X | | 1.324 | 9.4 | 1.098 | 17.1 | 0.882 | >31 |
| Andrews (MAC) | Micronized | X | | 1.431 | 7.5 | 1.185 | 12.1 | 0.945 | >31 |
| | Stoker refit | X | | 1.315 | 9.8 | 1.091 | 17.8 | 0.877 | >31 |
| Elmendorf ^b (AAC) | Micronized | X | | 1.527 | 8.5 | 1.146 | 14.3 | 0.851 | >31 |
| | Slagging | X | | 1.403 | 12.0 | 1.052 | 22.9 | 0.775 | >31 |
| | FBC refit | X | | 1.379 | 12.9 | 1.034 | 25.3 | 0.762 | >31 |
| | Field FBC | | X | 1.326 | 14.7 | 0.994 | >31 | 0.729 | >31 |
| Tinker (AFLC) | Field FBC | | X | 1.532 | 10.7 | 1.151 | 16.5 | 0.840 | >31 |
| | Pkg. FBC | | X | 1.523 | 10.4 | 1.145 | 16.3 | 0.839 | >31 |

^aLCC results for Pease may be optimistic because of questionable access to inexpensive rail delivery for coal.

^bLCC results for Elmendorf may be optimistic because of questionable availability of inexpensive coal.

6.3.2 Effect of Discount Rate

Lowering the discount rate will affect the LCC analysis because the influence of costs incurred in early years will become less important, and those incurred in later years will become more important. Another way to view this effect is that the influence of the initial capital investment will lessen in comparison to annual fuel and O&M costs. Lower discount rates will therefore cause coal projects to look more attractive.

A value of 10% was used for the discount rate in the main body of results. The LCC model was recalculated with a 7% discount rate for the top seven Air Force sites from Table 6.7. Because coal appears to be the least attractive relative to gas or oil for the zero fuel escalation case, this fuel escalation scenario was the only one evaluated. The results in Table 6.9 for Air Force-financed projects show that the 7% discount rate increases the magnitude of the benefit/cost ratios by about 3 or 4%, but it does not affect the ranking of the bases.

6.4 SUMMARY OF LEADING SITES FOR COAL UTILIZATION

The most important objective of this report is to conclude which Air Force sites have the greatest potential for economical utilization of coal. From the results given in Tables 6.3 to 6.9, seven bases can be identified as leading sites. This section summarizes the pertinent information for the seven leading sites: Arnold Air Force Station (AFS), Kelly AFB, Grand Forks AFB, Minot AFB, Robins AFB, Plattsburgh AFB, and McGuire AFB.

6.4.1 Arnold AFS

The main heating plant in Bldg. 1411 at Arnold consists of three 72-MBtu/h and one 24-MBtu/h boilers, all of which were designed for bituminous coal. The large boilers were designed for pulverized coal-firing. All of the boilers have been converted, and they now fire natural gas with No. 2 oil used as a secondary fuel. The boilers were installed in 1951, but they are still in good condition. The capacity factor for refitting or replacing one 72-MBtu/h boiler is estimated to be about 72%, based on FY 1986 fuel-use data.

Table 6.9. Effect of discount rate on Air Force-financing results for zero fuel escalation

| Base | 10% discount rate | | | | 7% Discount rate | | | |
|-------------|----------------------|------|--------------------|----------------------------|----------------------|------|--------------------|----------------------------|
| | Best coal technology | Rank | Benefit/cost ratio | Discounted payback (years) | Best coal technology | Rank | Benefit/cost ratio | Discounted payback (years) |
| Arnold | Micronized | 1 | 1.191 | 6.4 | Micronized | 1 | 1.230 | 5.9 |
| Kelly | Pkg. stoker | 3 | 1.022 | 19.3 | Pkg. stoker | 3 | 1.065 | 13.8 |
| Grand Forks | Micronized | 2 | 1.057 | 12.9 | Micronized | 2 | 1.096 | 10.6 |
| Minot | Micronized | 4 | 1.018 | 19.8 | Micronized | 4 | 1.057 | 14.0 |
| Robins | Micronized | 6 | 1.003 | 26.0 | Micronized | 6 | 1.034 | 15.9 |
| Plattsburgh | Micronized | 5 | 1.011 | 21.3 | Micronized | 5 | 1.042 | 14.6 |
| McGuire | Micronized | 7 | 0.950 | >31 | Micronized | 7 | 0.984 | >31 |

Some of the original coal-storage and -handling equipment is still in place, but it is in poor condition and could not be used again. Removal of this equipment would provide adequate space to install new coal-handling equipment. Because the large boilers were designed for pulverized coal-firing, the most convenient conversion would be to install micronized coal-firing equipment. The technical risk would be minimal, because the environmental regulations require no SO_2 control for a boiler with a fuel input <100 MBtu/h. A micronized coal system refit to one of the existing boilers is estimated to be the lowest-cost conversion option.

The economics of converting to coal-firing appear to be attractive based on both current and future escalated fuel prices. The current reported prices for fuels at the base are \$3.97/MBtu for natural gas and \$1.75/MBtu for ROM bituminous coal with 1.5% sulfur content. Overall, Arnold appears to be the leading candidate for conversion of one of the large boilers in the central steam plant back to coal-firing.

6.4.2 Kelly AFB

The main steam plant in Bldg. 376 at Kelly consists of two 54.5-MBtu/h, two 50-MBtu/h, and one 49.6-MBtu/h boilers that were designed for gas-/oil-firing. They use natural gas as the primary fuel with No. 2 oil as a secondary fuel. The boilers were installed from 1954 through 1976 and are in good condition. The capacity factor for refitting or replacing one 54.5-MBtu/h boiler, but derated to 43.5 MBtu/h, is estimated to be about 82%, based on FY 1985 fuel-use data. Derating is necessary because the boilers were not designed for coal-firing.

There is not enough available space at the existing boiler house to install dry coal-firing equipment or a coal pile. It should be possible to install coal/water mixture combustion equipment at the present boiler house. The technical risk would be fairly high because of limited experience with firing coal/water mixtures in No. 2 oil-designed boilers. A packaged shell-type stoker replacement boiler at another site on base is estimated to be the lowest-cost coal-conversion option. The environmental control regulations require no SO_2 control for boilers with ratings <100 MBtu/h fuel input.

Based on future escalated fuel prices, the economics of converting to coal-firing with a replacement boiler appear to be attractive. There is only a slight cost advantage at present fuel prices. The current reported prices for fuels at the base are \$4.00/MBtu for natural gas and \$1.98/MBtu for stoker bituminous coal with 1.3% sulfur. Kelly is among the top six candidates for potential conversion to coal-firing, in this case by means of a replacement boiler.

6.4.3 Grand Forks AFB

The central heating plant in Bldg. 423 at Grand Forks consists of two 42-MBtu/h and three 25-MBtu/h HTHW boilers, all of which were designed for stoker coal-firing. They were later converted to burn No. 6 oil. Presently, HTHW is being obtained from electrically heated boilers (owned by the electric utility) with a special low electric power rate of 2.15¢/kWh. However, No. 6 oil was assumed to be the primary fuel in the economic analysis because the contract to purchase this low-priced electric power from the utility will expire soon. The base also has recently acquired access to natural gas, but it has never been burned in the central heating plant. The capacity factor for refitting or replacing one 42-MBtu/h boiler is estimated to be ~72%, based on FY 1985 and 1986 fuel-use data.

The original coal-handling equipment has been removed, but there is space available to install new equipment. The boiler was originally designed for stoker-firing, so it should be feasible to refit it with any of the technology options. A refit to stoker-firing would have the least technical risk. The risk for the other options should be only slightly higher because the environmental regulations require no SO₂ control when burning low-sulfur coal (<1.6% sulfur) in a boiler with a fuel input <100 MBtu/h. A micronized coal system refit to one of the existing 42-MBtu/h boilers is estimated to be the lowest-cost conversion option.

The economics of converting to coal-firing appear to be favorable based on future escalated fuel prices. There is only a slight cost advantage at present fuel prices. The current reported prices for fuels at the base are \$3.67/MBtu for No. 6 oil or natural gas, and \$1.48/MBtu

for ROM bituminous coal with 1% sulfur. Grand Forks is among the top six candidates for conversion back to coal-firing, with the lowest-cost option being conversion of one of the 42-MBtu/h boilers to micronized coal.

6.4.4 Minot AFB

The central heating plant in Bldg. No. 413 at Minot consists of five 25-MBtu/h and one 42-MBtu/h HTMW boilers. Two boilers (42- and 25-MBtu/h) were designed to burn coal but have since been converted to burn gas or oil. Gas is the primary fuel, and No. 6 oil is the secondary fuel for these boilers. The 42-MBtu/h boiler was installed in 1963 and is in good condition. The capacity factor for refitting or replacing this boiler is estimated to be about 65%, based on FY 1985 and 1986 fuel-use data.

The original coal-handling equipment has been removed, but there is space available to install new equipment. The boiler was originally designed for stoker-firing, so it should be feasible to refit it with any of the technology options. A refit to stoker-firing would have the least technical risk. The risk for the other technology options should be only slightly higher because the environmental regulations require no SO₂ control when burning low-sulfur (<1.6%) coal in a boiler with a fuel input <100 MBtu/h. A micronized coal system refit to the existing 42-MBtu/h boiler is estimated to be the lowest-cost conversion option.

The economics of converting to coal-firing appear to be attractive based on future escalated fuel prices. There is only a slight cost advantage at present fuel prices. The current reported prices for fuels at the base are \$3.60/MBtu for natural gas and \$1.48/MBtu for ROM bituminous coal with 1% sulfur. Minot is one of the top six candidates for conversion back to coal-firing of the large boiler in the central heating plant.

6.4.5 Robins AFB

There are two major heating plants at Robins, but only one has large enough boilers to merit consideration for conversion. The larger heating plant in Bldg. 177 consists of three 98-MBtu/h, three 54-Btu/h,

and one 5-MBtu/h boilers. The three 54-MBtu/h boilers were originally designed for coal but have been converted to burn natural gas with No. 2 oil used as a secondary fuel. The boilers were installed in 1953 and are in fair condition. The capacity factor for refitting or replacing one 54-MBtu/h boiler is estimated to be ~81%, based on FY 1985 and 1986 fuel-use data.

The original coal-handling equipment has been removed, and cooling towers have been installed in much of this space. The space for new coal-handling equipment is limited, and the only technologies that could probably be used for refit would be micronized coal or coal/water slurry-firing. The micronized coal option would have the lowest technical risk because the environmental regulations require no SO₂ control for a boiler with a fuel input <100 MBtu/h. A micronized coal system refit to one of the existing 54-MBtu/h boilers is estimated to be the lowest-cost conversion option.

The economics of converting to coal-firing appear to be attractive based on future escalated fuel prices. There is only a slight cost advantage at present fuel prices. The current reported prices for fuels at the base are \$3.19/MBtu for natural gas and \$1.77/MBtu for ROM bituminous coal with 0.8% sulfur. Robins is one of the top six candidates for potential conversion back to coal-firing of one of the coal-designed boilers.

6.4.6 Plattsburgh AFB

The main heating plant in Bldg. 2658 at Plattsburgh consists of six 50-MBtu/h HTIW boilers, all of which were designed for firing No. 6 oil. The primary fuel is still No. 6 oil. The boilers were installed in 1955 and 1957 and are in fair to good condition. The capacity factor for refitting or replacing one 50-MBtu/h boiler is estimated to be about 76%, based on FY 1987 and 1988 fuel-use data.

There is enough space available to install coal-handling equipment and for a coal pile at the existing boiler house. Because the boilers were originally designed for No. 6 oil, the return to stoker option is not possible, but the other refit technologies should be feasible. The technical risk would be moderate for all of the refit options because of

limited experience with firing coal in boilers designed for No. 6 oil. A micronized coal system refit to one of the existing boilers is estimated to be the lowest-cost conversion option.

The economics of converting to coal-firing appear to be favorable based on future escalated fuel prices. There is only a slight cost advantage at present fuel prices. The current reported prices for fuels at the base are \$3.67/MBtu for No. 6 oil and \$1.97/MBtu for ROM bituminous coal with 2% sulfur. Plattsburgh is among the top seven candidates for conversion back to coal-firing, with the lowest-cost option being conversion of one of the 50-MBtu/h boilers to micronized coal.

6.4.7 McGuire AFB

The main heating plant in Bldg. 2101 at McGuire consists of four 50-MBtu/h and two 31.2-MBtu/h HTHW boilers, all of which were designed for stoker-firing of bituminous coal. All of the boilers have been converted and now burn natural gas with No. 2 oil used as a secondary fuel. The larger boilers were installed in 1953 and the smaller ones in 1960. The capacity factor for refitting or replacing one 50-MBtu/h boiler is estimated to be about 62% based on calendar year (CY) 1985 and FY 1986 fuel-use data.

Most of the coal-handling equipment is still in place, but some of it is in very bad condition and could not be used again. Removal of the unusable equipment would provide adequate space to install the necessary new coal-handling equipment. It would be feasible to refit one or more of the larger boilers with any of the technology options. The environmental regulations require strict SO₂ control, so the technical risk is fairly high for all of the combustion options. A micronized coal system refit to one of the 50-MBtu/h boilers is estimated to have the lowest cost of the conversion options, but low-sulfur (<1.5%) coal may be required in combination with limestone addition to meet the 0.3-lb/MBtu SO₂ emission limit.

The economics of converting to coal-firing appear to be favorable for future escalated fuel prices but unfavorable for current fuel prices. The current reported prices for fuels at the base are \$4.00/MBtu for natural gas and \$1.89/MBtu for ROM bituminous coal.

McGuire is among the top seven candidates for potential conversion to coal-firing.

7. CONCLUSIONS AND RECOMMENDATIONS

The major goal of this report was to rank the Air Force installations that presently burn natural gas and/or oil for steam/HTHW production according to their suitability for economical use of coal. It is recommended that the following seven installations be considered as the leading candidates for conversion of heating plants to coal-firing:

1. Arnold AFS,
2. Kelly AFB,
3. Grand Forks AFB,
4. Minot AFB,
5. Robins AFB,
6. Plattsburgh AFB,
7. McGuire AFB.

They are listed in order of rank, with Arnold AFS being the site with the highest estimated benefit/cost ratio for a coal-conversion/-utilization project. The ranking of all 16 Air Force sites examined in this report is given in Table 6.7.

Even though three levels of fuel escalation and two types of financing were considered, the economic results consistently identified Arnold AFS as the top site for coal conversion. The analysis also ranked Kelly, Grand Forks, Minot, Robins, Plattsburgh, and McGuire AFBs in positions 2 through 7, although their respective order was not always consistent. It is recommended that any possible demonstration projects be conducted at one of these seven bases. A micronized coal refit system would be a logical choice for a demonstration project because it is a fairly new technology that appears to have very favorable economics.

The three sets of fuel escalation assumptions used in the analysis did have a very significant effect on the calculated LCCs and benefit/cost ratios for the various coal-conversion projects. One fuel escalation scenario was based on DOD guidelines and resulted in rather high escalation rates for gas and oil prices relative to coal prices. It is

recommended that these DOD escalators be updated as soon as new information is available and that the current method for estimating fuel escalation beyond the year 2000 be improved. To address this issue, a second set of fuel escalators was developed and used in the LCC analysis for comparison. This second set of fuel price escalators was designated as the "AEO 1987" case, and it resulted in escalation rates that were approximately midway between the DOD fuel escalation rates and a third case of zero fuel escalation.

The results given in Tables 6.3 to 6.6 show a large spread in the benefit/cost ratios for the three different fuel price escalation scenarios. A large number of coal-conversion projects appear to be economically viable when the DOD fuel escalators are used; only a few appear economical when zero fuel escalation is assumed; and the middle "AEO 1987" fuel escalation case gives results between these extremes. It is very difficult to decide which fuel price scenario is most applicable because the fuel escalation projections are, at best, only educated guesses of future events. It can be concluded, however, that at least a few Air Force sites are good candidates for coal-conversion projects based on the results for zero fuel escalation, which is a very conservative assumption.

When compared to the DOD target of 1,600,000 tons/year, the coal-utilization projects considered in this report would result in a relatively small amount of coal use. Projects at all seven of the leading sites (listed previously) would consume only ~112,000 tons/year (~7% of DOD target). Projects at all 16 bases examined in the report would consume ~433,000 tons/year (~27% of DOD target). Other types of projects that would use greater amounts of coal should be examined if meeting the DOD target is desired. Coal-utilization projects that could potentially be larger than those examined in this study, such as cogeneration and increasing heating loads through distribution system extensions, will be examined in later reports.

Up to this point, noneconomic factors, such as Air Force energy security, aesthetics, and possible effects on base missions, have not been considered. These types of considerations must eventually be factored into the decision-making process.

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APPENDIX

AIR FORCE BASE INFORMATION SUMMARIES

Information summaries concerning the heating plants for each of the 16 Air Force facilities examined in the economic analysis are presented in this appendix. The information in these summaries was used to model coal-conversion projects. Results from the LCC model are included with each information summary.

The summaries are grouped according to the major commands and arranged alphabetically in the following order:

| <u>Base</u> | <u>Command</u> | <u>Page</u> |
|-----------------|----------------|-------------|
| Elmendorf AFB | AAC | 75 |
| Hill AFB | AFLC | 86 |
| Kelly AFB | AFLC | 96 |
| Robins AFB | AFLC | 106 |
| Tinker AFB | AFLC | 116 |
| Arnold AFS | AFSC | 126 |
| Hanscom AFB | AFSC | 135 |
| Andrews AFB | MAC | 145 |
| Dover AFB | MAC | 155 |
| McGuire AFB | MAC | 165 |
| Scott AFB | MAC | 175 |
| Grand Forks AFB | SAC | 185 |
| Minot AFB | SAC | 194 |
| Pease AFB | SAC | 203 |
| Plattsburgh AFB | SAC | 213 |
| USAF Academy | USAFA | 222 |

ELMENDORF AFB: AAC

1. BACKGROUND

Elmendorf Air Force Base is located near Anchorage, Alaska, and has one of the largest central heating plants in the Air Force. The annual average fuel consumption is ~300 MBtu/h. Only the primary heating plant is of significance to this study. All boilers were built to burn bituminous or subbituminous coals. They are described as field-erected, two-drum, bent-tube, water-tube units with economizers, fitted with Peabody ring-type gas burners and Peabody steam atomizing oil burners. Natural gas is now the main fuel with distillate (Arctic diesel) oil as a backup fuel. The boilers previously burned Matanuska bituminous coal (12,900 Btu/lb) with spreader stoker traveling grate systems. Conversion to natural gas (with Arctic diesel as secondary fuel) took place in 1968. The Matanuska mines went out of business because the remaining coal seam dipped steeply, causing mining to be uneconomical, especially in comparison to natural gas.

Presently, cogeneration is employed for this steam plant. The 415-psig superheated steam passes through three Westinghouse, 9375-kVA, condensing, single-automatic-extraction turbogenerators. Steam is extracted at 100 psig.

2. HEATING PLANT UNITS

Heating Plant No. 22-004:

6 x 150 MBtu/h, Erie City, 1954

3. IDEAL CAPACITY FACTOR ANALYSIS

The maximum possible capacity factors listed below were calculated from monthly fuel-use data for plant No. 22-004.

| Fuel input (MBtu/hr) | FY 1986 ideal capacity factor |
|----------------------------|--|
| 250 | 0.97 |
| 300 | 0.91 |
| 350 | 0.84 |
| 400 | 0.75 |
| 450 | 0.67 |

4. ENERGY PRICES

FY 1986 Price Data:

Natural gas = \$1.94/MBtu
 Distillate oil = \$5.90/MBtu
 Electricity = 8.0¢/kWh

The price of electricity is probably for the purchased amount only, which is rather small because of the cogeneration system.

C. H. Guernsey and Co. Survey:

Natural gas = \$2.05/MBtu
 Distillate oil = \$5.90/MBtu
 Electricity = 3.5¢/kWh

5. COAL PROPERTIES AND PRICES

| | <u>Stoker</u> | <u>ROM</u> |
|------------------------------|-------------------|------------|
| Origin | | |
| HHV, Btu/lb | 7650 | 7650 |
| Ash, % | 13.9 | 13.9 |
| Sulfur, % | 0.17 | 0.17 |
| Nitrogen, % | 1.0 | 1.0 |
| Ash-softening temperature °F | 2130 | 2130 |
| Swelling index | | |
| Top size, in. | 2 x 0 | |
| Bottom size, in. | | |
| Fines, % | | |
| Grindability index | 32 | 32 |
| Cost at mine, \$/ton | 31.00 (estimated) | 23.00 |
| Delivered cost, \$/ton | 33.00 | 25.00 |
| Energy price, \$/MBtu | 2.16 | 1.63 |

The prices quoted are very optimistic because they are from a new company that is not yet in operation. If the above coal is not available when a coal-conversion project is completed, then coal would have to be purchased from the only supplier that is currently in operation, at a delivered price of about \$44.00/ton (\$2.81/MBtu) for ROM coal. This would make coal conversion unattractive because coal would cost more than gas.

6. ENVIRONMENTAL REGULATIONS

6.1 Air Pollution Emission Limits for New Sources

The Air Quality Control Regulations of Alaska require that fuel-burning equipment of the capacity being considered for Elmendorf (one or more boilers) be operated only after a permit is granted. The application for a permit must include, in

addition to other requirements (1) plans and specifications, (2) an engineering report, and (3) a description of air-quality-control devices. The Air Quality Control Regulations classify the Anchorage urban area (adjacent to the base) as a nonattainment area (Class I) for carbon monoxide levels in the ambient air. Hence, carbon monoxide emissions may not increase significantly from current levels at the base unless an offset is adopted for another pollutant. A significant increase is defined in the national standards as 100 tpy. It is very unlikely that a return to coal-firing would violate this emission rate; hence, the increase in CO emission would in all probability not be significant.

With the exception of limited nonattainment areas for carbon monoxide, the air and water quality in Alaska compare favorably with most areas in the country. Therefore, the State government has not legislated Alaska air emission or coal runoff water standards but relies on applicable national standards for emission control.

SO₂. For boilers >100 MBtu/h: FBC - 90% reduction to meet limit of 1.2 lb/MBtu; emerging technology - 50% reduction to meet limit of 0.6 lb/MBtu.

NO_x. For boilers >100 MBtu/h: spreader stoker and FBC - 0.6 lb/MBtu; pulverized coal - 0.7 lb/MBtu.

Particulates. For boilers >100 MBtu/h: 0.05 lb/MBtu; opacity must be <20% except for one 6-min period per hour of no more than 27%.

6.2 Coal-Pile Runoff

EPA regulations for coal-pile rainfall runoff specify that the pH of all discharges, except once-through cooling water, shall be within the range of 6.0 to 9.0. The total suspended solids limitation for the point source discharges of coal-pile runoff is 50 mg/L.

6.3 Ash Disposal

The national standards for solid wastes classify coal ash as a nonhazardous solid waste. The EPA does not regulate fly ash and bottom ash waste. The only regulations Alaska has pertaining to or affecting coal ash disposal are (1) general requirements for a solid-waste facility and (2) rules for issuing a general permit for solid-waste disposal.

The general requirements for a solid-waste facility are designed to protect other standards governing the purity of surface- and drinking-water supplies. Problems should not

arise in this area if care is exercised in selecting a disposal site. Obtaining a general permit from the state of Alaska for disposal of solid waste should not present a problem since the waste is nonhazardous.

7. OTHER CONSIDERATIONS

Wages for steam plant personnel look very high, about \$17/h in 1980. Nineteen people were listed for this 900-MBtu/h boiler plant.

No doubt coal has some special problems in Alaska because of freezing temperatures. Also transportation difficulties and costs must be considered carefully. Railroad trackage is in poor condition and has been partially removed. No locomotive is available on base. The base has an expandable landfill to satisfy solid-waste disposal requirements.

8. COAL-CONVERSION PROJECT OUTLOOK

Based on the capacity factor analysis, the most economical coal options would probably be to replace/refit two boilers. The maximum load factor for conversion/replacement of two 150-MBtu/h units (375 MBtu/h fuel input for both units) would be ~0.80. If 90% coal system availability is assumed, then the estimated overall capacity factor for coal-firing will be $0.8 \times 0.9 = 0.72$.

8.1 Effect of Environmental Regulations on Selection of Combustion Technologies

SO₂. SO₂ removal is required because the proposed project is larger than 100 MBtu/h.

NO_x. No special NO_x reduction methods will be required for any of the combustion technologies.

Particulates. Bag filters or electrostatic precipitators will be required.

8.2 Physical Space and Aesthetics

Heating Plant. The existing plant was originally designed for coal. There is space available for reinstalling combustion equipment at the existing boiler or for constructing a new boiler at another site on base.

Coal-Handling Equipment. There is space available for coal-handling equipment at the existing boiler.

Coal Pile. There is space available for a coal pile at the existing plant or at a new site on base.

8.3 Technical Risk of Combustion Technologies

The boilers were originally designed for coal, and the lowest risk is for refit of stoker firing. However, the need for SO₂ control increases the overall risk for that option, as well as the other coal-combustion technologies.

9. COGENERATION PROJECT OUTLOOK

Cogeneration is currently being used at Elmendorf; hence, an evaluation of its potential is not provided.

10. INPUT AND LCC SUMMARY SPREADSHEETS

ELMENDORF AFB: 2 X 150 MBtu/hr. ECONOMIC PARAMETERS = NOMINAL VALUES

Total steam output = 300.0 MBtu/hr
 Boiler capacity factor = .719
 Number of units for refit = 2
 Hydrated lime price (\$/ton) = 40.00
 Ash disposal price (\$/ton) = 10.00
 Electric price (cents/kWh) = 3.50
 Labor rate (k\$/yr) = 35.00
 Limestone price (\$/ton) = 20.00

COAL PROPERTIES

| | R.O.M. | Stoker |
|-----------------|--------|--------|
| Ash fraction | .139 | .139 |
| Sulfur fraction | .002 | .002 |
| HHV (Btu/lb) | 7650. | 7650. |

FUEL PRICES
 Natural gas price (\$/MBtu) = 2.05
 #2 Oil price (\$/MBtu) = 4.71
 #6 Oil price (\$/MBtu) = .00

OPTIONS
 Scot blower multiplier = .0
 Tube bank mod multiplier = .0
 Bottom ash pit multiplier = 1.0
 SO2 control multiplier = 1.0

LIMESTONE/LIME
 Inert fraction = .05

FUEL PRICES
 R.O.M. coal (\$/MBtu) = 1.83
 Stoker coal (\$/MBtu) = 2.16
 Coal/H2O mix (\$/MBtu) = 3.00
 Coal/oil mix (\$/MBtu) = 3.50

Primary fuel is 3
NATURAL GAS
 1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988
 Gen infla index (1987 to base yr) = 1.046
 Gas infla index (1988 to base yr) = 1.000
 Oil infla index (1988 to base yr) = 1.000
 Coal infla index (1988 to base yr) = 1.000
 Project start year = 1990
 Project life (yr) = 30
 Depreciation life (yr) = 15
 General inflation rate (I/yr) = 0
 Type of gas escalation = egas
 Type of oil escalation = eoil
 Type of coal escalation = ecoal
 Discount rate (I/yr) = 10
 Rate of return on invest (I/yr) = 17
 Amount of working capital (month) = 2
 Federal income tax rate (I) = 34
 Local prop tax (& insur) rate (I) = 2

| FUEL | TYPE OF FUEL ESCALATION | REAL ESCALATION RATE (I/yr) | | | |
|------|----------------------------|-----------------------------|---------------|---------------|--------------------|
| | | 1988 -1990 | 1990 -1995 | 1995 -2000 | 2000 AND BEYOND |
| Gas | egas | 3.89 | 8.67 | 5.77 | 5.77 |
| Oil | eoil | 4.86 | 7.87 | 4.16 | 4.16 |
| Coal | ecoal | 1.16 | 2.31 | 1.19 | 1.19 |

3:45 PM Oct 24, 1988

WINDORP AFB: 2 X 150 Mtu/hr. ECONOMIC PARAMETERS = NOMINAL VALUES

Total steam output = 300.0 Mtu/hr

Cost base year = 1988

Boiler capacity factor = .719

Primary fuel = NATURAL GAS

Number of units for refit = 2

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/Mtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|-------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | OTHER O & M k\$ |
| Natural gas boiler | -- | .803 | 2.05 | .0 | 4841.9 | 443.2 | 817.8 |
| #2 Oil fired boiler | -- | .800 | 4.71 | .0 | 11124.6 | 443.2 | 817.8 |
| #6 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| Micronized coal refit | 2 | .800 | 1.63 | 9386.9 | 3849.9 | 724.1 | 1573.8 |
| Slagging burner refit | 2 | .800 | 1.63 | 16028.4 | 3849.9 | 724.1 | 1573.8 |
| Modular FBC refit | 2 | .790 | 1.63 | 18351.8 | 3898.7 | 667.9 | 1486.4 |
| Stoker firing refit | 2 | .740 | 2.16 | 16257.6 | 5515.4 | 1060.0 | 1567.3 |
| Coal/water slurry | 2 | .750 | 3.00 | 6696.0 | 7558.1 | 667.9 | 1361.9 |
| Coal/oil slurry | 2 | .780 | 3.50 | 7728.6 | 8478.7 | 531.9 | 1133.6 |
| Low Btu gasifier refit | 6 | .659 | 2.16 | 27376.7 | 6107.1 | 616.0 | 3377.1 |
| Packaged shell stoker | 6 | .740 | 2.16 | 26976.7 | 5515.4 | 1060.0 | 1806.2 |
| Packaged shell FBC | 6 | .760 | 1.63 | 25097.4 | 4052.5 | 667.9 | 1737.8 |
| Field erected stoker | 1 | .780 | 2.16 | 24711.4 | 5232.6 | 1055.9 | 1396.5 |
| Field erected FBC | 1 | .800 | 1.63 | 22309.6 | 3849.9 | 775.7 | 1358.8 |
| Pulverized coal boiler | 1 | .800 | 1.63 | 28117.7 | 3849.0 | 1175.9 | 1460.8 |
| Circulating FBC | 1 | .810 | 1.63 | 28500.3 | 3802.4 | 663.9 | 1470.6 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|---------------|------------------|--|---------------------|------------------------------------|--|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO | PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 95,354 | 1.000 | <--- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 179,723 | -- | | | |
| #6 Oil fired boiler | -- | -- | 0 | -- | | | |
| Micronized coal refit | 2 | 154,374 | 62,462 | 1.527 | 8.5 | 68,800 | 1.386 |
| Slagging burner refit | 2 | 154,374 | 67,951 | 1.403 | 12.0 | 77,676 | 1.228 |
| Modular FBC refit | 2 | 156,328 | 69,143 | 1.379 | 12.9 | 80,032 | 1.191 |
| Stoker firing refit | 2 | 166,890 | 86,653 | 1.100 | 23.2 | 97,019 | .983 |
| Coal/water slurry | 2 | 164,665 | 94,382 | 1.010 | 30.0 | 101,288 | .841 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | 6 | 187,517 | 112,341 | .849 | >31 | 128,846 | .740 |
| Packaged shell stoker | 6 | 166,890 | 97,373 | .979 | >31 | 113,259 | .842 |
| Packaged shell FBC | 6 | 162,498 | 78,115 | 1.221 | 18.2 | 92,541 | 1.030 |
| Field erected stoker | 1 | 158,332 | 89,630 | 1.064 | 25.9 | 104,194 | .915 |
| Field erected FBC | 1 | 154,374 | 71,929 | 1.326 | 14.7 | 84,823 | 1.124 |
| Pulverized coal boiler | 1 | 154,374 | 81,256 | 1.174 | 20.3 | 97,241 | .981 |
| Circulating FBC | 1 | 152,468 | 76,471 | 1.247 | 17.6 | 92,507 | 1.031 |

ELMENDORF AFB: 2 X 150 MBtu/hr. FUEL REAL ESCALATION - AEO 1987

Total steam output = 300.0 MBtu/hr

Boiler capacity factor = .719

Number of units for refit = 2

Hydrated lime price (\$/ton) = 40.00

Ash disposal price (\$/ton) = 10.00

Electric price (cents/kWh) = 3.50

Labor rate (k\$/yr) = 35.00

Limestone price (\$/ton) = 20.00

FUEL PRICES

Natural gas price (\$/MBtu) = 2.05

#2 Oil price (\$/MBtu) = 4.71

#6 Oil price (\$/MBtu) = .00

OPTIONS

Soot blower multiplier = .0

Tube bank mod multiplier = .0

Bottom ash pit multiplier = 1.0

SO2 control multiplier = 1.0

LIMESTONE/LIME

Inert fraction = .05

COAL PROPERTIES

R.O.M. Stoker

Ash fraction = .139 .139

Sulfur fraction = .002 .002

HHV (Btu/lb) = 7650. 7650.

FUEL PRICES

R.O.M. coal (\$/MBtu) = 1.63

Stoker coal (\$/MBtu) = 2.16

Coal/H2O mix (\$/MBtu) = 3.00

Coal/oil mix (\$/MBtu) = 3.50

Primary fuel is 3

NATURAL GAS

1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988

Gen infla index (1987 to base yr) = 1.040

Gas infla index (1988 to base yr) = 1.000

Oil infla index (1988 to base yr) = 1.000

Coal infla index (1988 to base yr) = 1.000

Project start year = 1990

Project life (yr) = 30

Depreciation life (yr) = 15

General inflation rate (X/yr) = 0

Type of gas escalation = egas

Type of oil escalation = eoil

Type of coal escalation = ecoal

Discount rate (X/yr) = 10

Rate of return on invest (X/yr) = 17

nt of working capital (month) = 2

Federal income tax rate (X) = 34

Local prop tax (& insur) rate (X) = 2

REAL ESCALATION RATE (X/yr)

| FUEL | TYPE OF FUEL ESCALATION | 1988 | 1990 | 1995 | 2000 AND |
|------|----------------------------|-------|-------|-------|----------|
| | | -1990 | -1995 | -2000 | BEYOND |
| Gas | egas | 2.28 | 4.70 | 5.40 | 2.75 |
| Oil | eoil | .17 | 4.16 | 5.55 | 2.77 |
| Coal | ecoal | 1.46 | 1.76 | 1.61 | .81 |

3:52 PM Oct 24, 1988

ELMENDORF AFB: 2 X 150 MBtu/hr. FUEL REAL ESCALATION - AFO 1987

Total steam output = 300.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .719

Primary fuel = NATURAL GAS

Number of units for refit = 2

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | OTHER O & M k\$ |
| Natural gas boiler | -- | .800 | 2.05 | .0 | 4841.9 | 443.2 | 817.8 |
| #2 Oil fired boiler | -- | .800 | 4.71 | .0 | 11124.6 | 443.2 | 817.8 |
| #6 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| Micronized coal refit | 2 | .800 | 1.63 | 9386.9 | 3849.9 | 724.1 | 1573.8 |
| Slagging burner refit | 2 | .800 | 1.63 | 16028.4 | 3849.9 | 724.1 | 1573.8 |
| Modular FBC refit | 2 | .790 | 1.63 | 18351.6 | 3898.7 | 667.9 | 1486.4 |
| Stoker firing refit | 2 | .740 | 2.16 | 16257.6 | 5515.4 | 1060.0 | 1567.3 |
| Coal/water slurry | 2 | .750 | 3.00 | 8696.0 | 7558.1 | 667.9 | 1361.0 |
| Coal/oil slurry | 2 | .780 | 3.50 | 7728.6 | 8478.7 | 531.9 | 1133.6 |
| Low Btu gasifier refit | 6 | .859 | 2.16 | 27376.7 | 6107.1 | 616.0 | 3377.1 |
| Packaged shell stoker | 6 | .740 | 2.16 | 26976.7 | 5515.4 | 1060.0 | 1806.2 |
| Packaged shell FBC | 6 | .760 | 1.63 | 25097.4 | 4052.5 | 667.9 | 1737.8 |
| Field erected stoker | 1 | .780 | 2.16 | 24711.4 | 5232.6 | 1055.9 | 1396.5 |
| Field erected FBC | 1 | .800 | 1.63 | 22309.6 | 3849.9 | 775.7 | 1358.8 |
| Pulverized coal boiler | 1 | .800 | 1.63 | 28117.7 | 3849.9 | 1175.9 | 1480.6 |
| Circulating FBC | 1 | .810 | 1.63 | 28560.3 | 3802.4 | 663.9 | 1470.6 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|---------------|------------------|--|---------------------|------------------------------------|--|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO | PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 70,854 | 1.000 | <--- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 141,045 | -- | | | |
| #6 Oil fired boiler | -- | -- | 0 | -- | | | |
| Micronized coal refit | 2 | 154,374 | 61,850 | 1.146 | 14.3 | 68,170 | 1.039 |
| Slagging burner refit | 2 | 154,374 | 67,339 | 1.052 | 22.9 | 77,046 | .920 |
| Modular FBC refit | 2 | 156,328 | 68,523 | 1.034 | 25.3 | 79,395 | .892 |
| Stoker firing refit | 2 | 166,890 | 85,776 | .826 | >31 | 96,117 | .737 |
| Coal/water slurry | 2 | 164,665 | 93,180 | .760 | >31 | 100,052 | .708 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | 6 | 187,517 | 111,355 | .636 | >31 | 127,832 | .554 |
| Packaged shell stoker | 6 | 166,890 | 96,466 | .734 | >31 | 112,357 | .631 |
| Packaged shell FBC | 6 | 162,498 | 77,470 | .915 | >31 | 91,878 | .771 |
| Field erected stoker | 1 | 158,332 | 88,798 | .798 | >31 | 103,339 | .686 |
| Field erected FBC | 1 | 154,374 | 71,317 | .994 | >31 | 84,194 | .842 |
| Pulverized coal boiler | 1 | 154,374 | 80,644 | .879 | >31 | 96,611 | .733 |
| Circulating FBC | 1 | 152,468 | 75,867 | .934 | >31 | 91,883 | .771 |

3:52 PM Oct 24, 1988

ELMENDORF AFB: 2 X 150 Mbtu/hr. FUEL RES, ESCALATION = ZERO

Total steam output = 300.0 Mbtu/hr

Boiler capacity factor = .719

Number of units for refit = 2

Hydrated lime price (\$/ton) = 40.00

Ash disposal price (\$/ton) = 10.00

Electric price (cents/kWh) = 3.50

Labor rate (k\$/yr) = 35.00

Limestone price (\$/ton) = 20.00

FUEL PRICES

Natural gas price (\$/Mbtu) = 2.05

#2 Oil price (\$/Mbtu) = 4.71

#6 Oil price (\$/Mbtu) = .00

OPTIONS

Soot blower multiplier = .0

Tube bank mod multiplier = .0

Bottom ash pit multiplier = 1.0

SO2 control multiplier = 1.0

LIMESTONE/LIME

Inert fraction = .05

COAL PROPERTIESR.O.M. Stoker

Ash fraction = .139 .139

Sulfur fraction = .002 .002

HHV (Btu/lb) = 7650. 7650.

FUEL PRICES

R.O.M. coal (\$/Mbtu) = 1.63

Stoker coal (\$/Mbtu) = 2.16

Coal/H2O mix (\$/Mbtu) = 3.00

Coal/oil mix (\$/Mbtu) = 3.50

Primary fuel is 3

NATURAL GAS

1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988

Gen infla index (1987 to base yr) = 1.040

Gas infla index (1988 to base yr) = 1.000

Oil infla index (1988 to base yr) = 1.000

Coal infla index (1988 to base yr) = 1.000

Project start year = 1990

Project life (yr) = 30

Depreciation life (yr) = 15

General inflation rate (I/yr) = 0

Type of gas escalation = zero

Type of oil escalation = zero

Type of coal escalation = zero

Discount rate (I/yr) = 10

Rate of return on invest (I/yr) = 17

Amount of working capital (month) = 2

Federal income tax rate (I) = 34

Local prop tax (& insur) rate (I) = 2

| | | <u>REAL ESCALATION RATE (I/yr)</u> | | | |
|-------------|---------------------|------------------------------------|-------|-------|----------|
| | <u>TYPE OF FUEL</u> | 1988 | 1990 | 1995 | 2000 AND |
| <u>FUEL</u> | <u>ESCALATION</u> | -1990 | -1995 | -2000 | BEYOND |
| Gas | zero | 0 | 0 | 0 | 0 |
| Oil | zero | 0 | 0 | 0 | 0 |
| Coal | zero | 0 | 0 | 0 | 0 |

3:59 PM Oct 24, 1988

WIMBORNE AFB: 2 X 150 MBtu/hr. FUEL REAL ESCALATION = ZERO

Total steam output = 350.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .719

Primary fuel = NATURAL GAS

Number of units for refit = 2

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL \$K | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL \$K | MAINT O & M \$K | OTHER O & M \$K |
| | | | | | \$K | \$K | \$K |
| Natural gas boiler | -- | .800 | 2.05 | .0 | 4841.8 | 443.2 | 817.8 |
| #2 Oil fired boiler | -- | .800 | 4.71 | .0 | 11121.6 | 443.2 | 817.8 |
| #6 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| Micronized coal refit | 2 | .800 | 1.63 | 9386.0 | 3840.0 | 724.1 | 1573.8 |
| Slagging burner refit | 2 | .800 | 1.63 | 16028.4 | 3840.0 | 724.1 | 1573.8 |
| Modular FBC refit | 2 | .790 | 1.63 | 18351.6 | 3898.7 | 667.9 | 1486.4 |
| Stoker firing refit | 2 | .740 | 2.16 | 16257.6 | 5315.4 | 1060.0 | 1567.3 |
| Coal/water slurry | 2 | .750 | 3.00 | 8626.0 | 7558.1 | 667.9 | 1361.0 |
| Coal/oil slurry | 2 | .780 | 3.50 | 7726.6 | 8478.7 | 531.0 | 1133.6 |
| Low Btu gasifier refit | 6 | .652 | 2.16 | 27376.7 | 8197.1 | 616.0 | 3377.1 |
| Packaged shell stoker | 6 | .740 | 2.16 | 26978.7 | 5515.4 | 1060.0 | 1806.2 |
| Packaged shell FBC | 6 | .760 | 1.63 | 25097.4 | 4052.5 | 667.9 | 1737.8 |
| Field erected stoker | 1 | .780 | 2.16 | 24711.4 | 5232.0 | 1055.9 | 1396.5 |
| Field erected FBC | 1 | .800 | 1.63 | 22309.6 | 3849.9 | 775.7 | 1358.8 |
| Pulverized coal boiler | 1 | .800 | 1.63 | 28117.7 | 3849.0 | 1175.0 | 1480.6 |
| Circulating FBC | 1 | .810 | 1.63 | 26500.3 | 3802.4 | 663.9 | 1470.6 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|---------------|------------------|--|---------------------|--------------------|--|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT \$K | BENEFIT/ COST RATIO | PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT \$K | BENEFIT/ COST RATIO |
| | | | \$K | RATIO | yr | \$K | RATIO |
| Natural gas boiler | -- | -- | 48,057 | 1.000 | <--- | Existing system, primary fuel | |
| #2 Oil fired boiler | -- | -- | 97,005 | -- | | | |
| #6 Oil fired boiler | -- | -- | 0 | -- | | | |
| Micronized coal refit | 2 | 154,374 | 56,488 | .851 | >31 | 62,656 | .767 |
| Slagging burner refit | 2 | 154,374 | 61,977 | .775 | >31 | 71,532 | .672 |
| Modular FBC refit | 2 | 156,328 | 63,093 | .762 | >31 | 73,811 | .651 |
| Stoker firing refit | 2 | 166,890 | 78,094 | .615 | >31 | 88,218 | .545 |
| Coal/water slurry | 2 | 164,665 | 82,653 | .581 | >31 | 89,227 | .539 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | 6 | 187,517 | 102,724 | .468 | >31 | 118,957 | .404 |
| Packaged shell stoker | 6 | 166,890 | 88,814 | .541 | >31 | 104,457 | .460 |
| Packaged shell FBC | 6 | 162,498 | 71,826 | .669 | >31 | 86,074 | .558 |
| Field erected stoker | 1 | 158,332 | 81,510 | .590 | >31 | 95,844 | .501 |
| Field erected FBC | 1 | 154,374 | 65,955 | .729 | >31 | 78,679 | .611 |
| Pulverized coal boiler | 1 | 154,374 | 75,282 | .638 | >31 | 91,097 | .528 |
| Circulating FBC | 1 | 152,468 | 70,571 | .681 | >31 | 86,439 | .556 |

HILL AFB: AFLC

1. BACKGROUND

Hill AFB is located near Ogden, Utah. There are about 13 steam plants located on this base, with plant No. 260 being by far the largest fuel user (yearly average is ~115 MBtu/h). Boiler plant No. 825 is the second largest fuel-using heating facility, but it is probably too small for coal to be an economic option.

Boilers at both heating plants are water-tube-type units which produce 100 psi steam and are designed for distillate oil and natural gas-firing. Natural gas is presently the primary fuel.

2. HEATING PLANT UNITS

Heating Plant No. 260:

2 x 28.5 MBtu/h, Cleaver Brooks, 1975
 4 x 33.5 MBtu/h, Union Iron Works, 1955
 2 x 33.5 MBtu/h, Erie City, 1962

Heating plant No. 825:

3 x 40.2 MBtu/h, Murray Iron, 1957

3. IDEAL CAPACITY FACTOR ANALYSIS

The ideal capacity factors listed below were calculated from monthly fuel use data for plant No. 260.

| Fuel input (MBtu/h) | FY 1985 ideal capacity factor |
|---------------------------|--|
| 30 | 0.83 |
| 50 | 0.81 |
| 70 | 0.75 |
| 90 | 0.71 |
| 120 | 0.67 |
| 150 | 0.64 |
| 180 | 0.61 |

4. ENERGY PRICES

FY 1986 Price Data:

Electricity = 5.2¢/kWh
 Distillate = \$5.92/MBtu
 Natural gas = \$2.85/MBtu

C. H. Guernsey and Co. Sur γ:

Electricity = none given
 Distillate = \$5.63/MBtu
 Natural gas = \$2.97/MBtu

5. COAL PROPERTIES AND PRICES

| | <u>Stoker</u> | <u>ROM</u> |
|-------------------------------------|---------------|-------------|
| Origin | Ogden, Utah | Ogden, Utah |
| HHV, Btu/lb | 11,900 | 11,650 |
| % Ash | 8 | 8 |
| % Sulfur | 0.6 | 0.6 |
| % Nitrogen | 1.4 | 1.4 |
| Ash-softening temperature, °F | 2300 | 2300 |
| Swelling index | 2-2.5 | 2-2.5 |
| Top size, in. | 1 1/2 | 2 |
| Bottom size, in. | 1/4 | 0 |
| Fines, % | 7 | 35 |
| Grindability index | 48-50 | 48-50 |
| Cost at mine, \$/ton | 23 | 20 |
| Delivered cost, \$/ton | 31 | 28 |
| Energy cost, \$/10 ⁶ Btu | 1.30 | 1.20 |

6. ENVIRONMENTAL REGULATIONS

6.1 Air Pollution Emission Limits for New Sources

Best Available Control Technology (BACT) is required on all sources for all types of air emissions. The EPA New Source Performance Standards are considered as the minimum control, and BACT may be more stringent. This is determined on a case-by-case basis.

6.2 Coal-Pile Runoff

The coal pile will have to be contained within the property, and the runoff will have to drain into a wastewater system (or pond) for treatment. No discharge into rivers will be permitted.

6.3 Ash Disposal

There are no specific rules for coal ashes, and they may be disposed of in an approved sanitary landfill.

7. OTHER CONSIDERATIONS

A study should be done to see if some of the smaller steam plants could be eliminated by using a better steam distribution system. Air-quality constraints appear to be strict.

8. COAL-CONVERSION PROJECT OUTLOOK

The most probable project for plant No. 260 would involve refit/replacement of three 33.5-MBtu/h boilers. The boilers would have to be derated to 25 MBtu/h each because they were originally designed for No. 2 oil. Low gas prices will probably prevent any coal conversion project from being economical at this time.

An overall load factor of about 64% is estimated for refit/replacement of three 25-MBtu/h units (equivalent to ~94 MBtu/h total fuel input), assuming 90% availability.

8.1 Effect of Environmental Regulations on Selection of Combustion Technologies

SO₂. Since the best available Control Technology is required, 90% SO₂ reduction will be required for dry coal combustion, or deep-cleaned, coal-water mixture will be required.

NO_x. Measures will have to be taken to minimize NO_x for any of the combustion technologies employed.

Particulates. Bag filters or electrostatic precipitators will be required.

8.2 Physical Space and Aesthetics

Heating Plant. The existing boiler plant was originally designed for No. 2 oil. There is only enough space available for installing coal-water-mixture combustion equipment at the existing boiler or for construction of a new boiler at another site on base.

Coal-Handling Equipment. There is no space available for installing dry coal-handling equipment at the existing boiler plant, but there is enough space for installing coal-water-mixture equipment.

Coal Pile. There is no available space for a coal pile at the existing boiler plant, but there is space at another site on base for a coal pile and a new coal-fired boiler.

8.3 Technical Risk of Combustion Technologies

The existing boilers are designed for No. 2 oil- or gas-firing and therefore are only suitable for conversion to coal-water-mixture firing. The technical risk is fairly high because of limited experience of coal-water-mixture firing of No. 2 oil-designed boilers.

9. COGENERATION PROJECT OUTLOOK

The prospects for a coal-fired cogeneration system appear to be somewhat marginal. The base has a high minimum monthly average electric load, 15 MWe, but the price of electricity is moderate (5.2¢/kWh). Based on the FY 1986 energy-use data, a cogeneration plant with a boiler rating of 91-MBtu/h output and a 6.7-MWe turbine generator would have an electrical power capacity factor of 90% and a peak thermal output of 68 MBtu/h, with a thermal energy capacity factor of about 65% if used as a baseload heating plant. A water-tube boiler with a steam rating of 1450 psia and 950°F would be the most suitable boiler for this cogeneration system.

10. INPUT AND LCC SUMMARY SPREADSHEETS

HILL AFB: 3 X 25 MBtu/hr. ECONOMIC PARAMETERS - NOMINAL VALUES

| | |
|--|--|
| Total steam output = 75.0 MBtu/hr | |
| Boiler capacity factor = .635 | |
| Number of units for refit = 3 | |
| Hydrated lime price (\$/ton) = 40.00 | COAL PROPERTIES |
| Ash disposal price (\$/ton) = 10.00 | R.O.M. Stoker |
| Electric price (cents/kWh) = 5.20 | Ash fra on = .080 .080 |
| Labor rate (\$/yr) = 35.00 | Sulfur fra on = .008 .008 |
| Limestone price (\$/ton) = 20.00 | HHV (P, lb) = 11650. 11900. |
| FUEL PRICES | FUEL PRICE |
| Natural gas price (\$/MBtu) = 2.97 | R.O.M. coal (MBtu) = 1.20 |
| #2 Oil price (\$/MBtu) = 4.71 | Stoker coal (MBtu) = 1.30 |
| #6 Oil price (\$/MBtu) = .60 | Coal/H ₂ O mix (\$/MBtu) = 3.00 |
| OPTIONS | Coal/oil mix (\$/MBtu) = 3.50 |
| Soot blower multiplier = 1.0 | |
| Tube bank mod multiplier = 1.0 | Primary fuel is 3 |
| Bottom ash pit multiplier = 1.0 | NATURAL GAS |
| SO ₂ control multiplier = 1.0 | 1-#6 Oil, 2-#2 Oil, 3-NG |
| LIMESTONE/LIME | |
| Inert fraction = .05 | |

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988
 Gen infla index (1987 to base yr) = 1.040
 Gas infla index (1988 to base yr) = 1.000
 Oil infla index (1988 to base yr) = 1.000
 Coal infla index (1988 to base yr) = 1.000
 Project start year = 1990
 Project life (yr) = 30
 Depreciation life (yr) = 15
 General inflation rate (X/yr) = 0
 Type of gas escalation = egas
 Type of oil escalation = eoil
 Type of coal escalation = ecoal
 Discount rate (X/yr) = 10
 Rate of return on invest (X/yr) = 17
 Amount of working capital (month) = 2
 Federal income tax rate (X) = 34
 Local prop tax (& insur) rate (X) = 2

| | | REAL ESCALATION RATE (X/yr) | | | |
|------|--------------|-----------------------------|-------|-------|----------|
| | TYPE OF FUEL | 1988 | 1990 | 1995 | 2000 AND |
| FUEL | ESCALATION | -1990 | -1995 | -2000 | BEYOND |
| Gas | egas | 3.89 | 8.87 | 5.77 | 5.77 |
| Oil | eoil | 4.86 | 7.87 | 4.16 | 4.16 |
| Coal | ecoal | 1.16 | 2.31 | 1.19 | 1.19 |

4:58 PM Oct 19, 1988

FILL AFB: 3 X 25 MBtu/hr. ECONOMIC PARAMETERS - NOMINAL VALUES

Total steam output = 75.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .635

Primary fuel = NATURAL GAS

Number of units for refit = 3

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | OTHER O & M k\$ |
| Natural gas boiler | -- | .800 | 2.97 | .0 | 1548.8 | 206.8 | 535.8 |
| #2 Oil fired boiler | -- | .800 | 4.71 | .0 | 2456.2 | 206.8 | 535.8 |
| #6 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| Micronized coal refit | 3 | .800 | 1.20 | 5449.5 | 625.8 | 440.8 | 935.9 |
| Slagging burner refit | 3 | .800 | 1.20 | 8867.9 | 625.8 | 440.8 | 935.9 |
| Modular FBC refit | 3 | .790 | 1.20 | 10055.0 | 633.7 | 405.5 | 905.2 |
| Stoker firing refit | 3 | .740 | 1.30 | 8072.0 | 732.9 | 630.7 | 923.6 |
| Coal/water slurry | 3 | .750 | 3.00 | 5411.4 | 1668.8 | 405.5 | 802.2 |
| Coal/oil slurry | 3 | .780 | 3.50 | 4453.0 | 1872.0 | 322.9 | 738.2 |
| Low Btu gasifier refit | 3 | .659 | 1.30 | 8971.8 | 823.5 | 374.0 | 1310.5 |
| Packaged shell stoker | 2 | .740 | 1.30 | 7747.4 | 732.9 | 630.7 | 860.1 |
| Packaged shell FBC | 2 | .760 | 1.20 | 7263.5 | 658.7 | 405.5 | 844.0 |
| Field erected stoker | 1 | .780 | 1.30 | 10158.7 | 695.3 | 628.2 | 750.3 |
| Field erected FBC | 1 | .800 | 1.20 | 9245.3 | 625.8 | 470.9 | 744.7 |
| Pulverized coal boiler | 1 | .800 | 1.20 | 11543.5 | 625.8 | 701.0 | 802.7 |
| Circulating FBC | 1 | .810 | 1.20 | 11141.2 | 618.1 | 403.0 | 800.8 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|--|------------------|--|---------------------|------------------------------------|--|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO | PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 33,218 | 1.000 | <--- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 43,422 | -- | | | |
| #6 Oil fired boiler | -- | -- | 0 | -- | | | |
| Micronized coal refit | Not applicable because of space limitations | | | | | | |
| Slagging burner refit | Not applicable because of space limitations | | | | | | |
| Modular FBC refit | Not applicable because of space limitations | | | | | | |
| Stoker firing refit | Not applicable because existing boilers were designed for #2 oil | | | | | | |
| Coal/water slurry | 3 | 23,874 | 29,939 | 1.110 | 22.0 | 33,420 | .994 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | Not applicable because of space limitations | | | | | | |
| Packaged shell stoker | 2 | 23,688 | 25,590 | 1.298 | 15.0 | 30,085 | 1.104 |
| Packaged shell FBC | 2 | 23,550 | 22,358 | 1.486 | 11.0 | 26,526 | 1.252 |
| Field erected stoker | 1 | 22,473 | 26,355 | 1.260 | 16.8 | 32,045 | 1.037 |
| Field erected FBC | 1 | 22,382 | 23,500 | 1.414 | 13.0 | 28,664 | 1.159 |
| Pulverized coal boiler | 1 | 22,382 | 27,909 | 1.190 | 19.5 | 34,317 | .968 |
| Circulating FBC | 1 | 22,105 | 24,824 | 1.338 | 15.1 | 30,949 | 1.073 |

HILL AFB: 3 X 25 MBtu/hr. FUEL REAL ESCALATION - AYO 1987

Total steam output = 75.0 MBtu/hr

Boiler capacity factor = .635

Number of units for refit = 3

Hydrated lime price (\$/ton) = 40.00

Ash disposal price (\$/ton) = 10.00

Electric price (cents/kWh) = 5.20

Labor rate (k\$/yr) = 35.00

Limestone price (\$/ton) = 20.00

FUEL PRICES

Natural gas price (\$/MBtu) = 2.97

#2 Oil price (\$/MBtu) = 4.71

#6 Oil price (\$/MBtu) = .00

OPTIONS

Soot blower multiplier = 1.0

Tube bank mod multiplier = 1.0

Bottom ash pit multiplier = 1.0

SO2 control multiplier = 1.0

LIMESTONE/LIME

Inert fraction = .05

COAL PROPERTIES

R.O.M. Stoker

Ash fraction = .080 .080

Sulfur fraction = .006 .006

HHV (Btu/lb) = 11650. 11900.

FUEL PRICES

R.O.M. coal (\$/MBtu) = 1.20

Stoker coal (\$/MBtu) = 1.30

Coal/H2O mix (\$/MBtu) = 3.00

Coal/oil mix (\$/MBtu) = 3.50

Primary fuel is 3

NATURAL GAS

1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988

Gen infla index (1987 to base yr) = 1.040

Gas infla index (1988 to base yr) = 1.000

Oil infla index (1988 to base yr) = 1.000

Coal infla index (1988 to base yr) = 1.000

Project start year = 1990

Project life (yr) = 30

Depreciation life (yr) = 15

General inflation rate (I/yr) = 0

Type of gas escalation = egas

Type of oil escalation = eoil

Type of coal escalation = ecoal

Discount rate (I/yr) = 10

Rate of return on invest (I/yr) = 17

Amount of working capital (month) = 2

Federal income tax rate (I) = 34

Local prop tax (& insur) rate (I) = 2

REAL ESCALATION RATE (I/yr)

| FUEL | TYPE OF FUEL ESCALATION | 1988 | 1990 | 1995 | 2000 AND |
|------|----------------------------|-------|-------|-------|----------|
| | | -1990 | -1995 | -2000 | BEYOND |
| Gas | egas | 2.28 | 4.70 | 5.49 | 2.75 |
| Oil | eoil | .17 | 4.16 | 5.55 | 2.77 |
| Coal | ecoal | 1.46 | 1.76 | 1.61 | .81 |

5:04 PM Oct 19, 1988

HILL AFB: 3 X 25 MBtu/hr. FUEL REAL ESCALATION - AEO 1987

Total steam output = 75.0 MBtu/hr

Cost base year = 1968

Boiler capacity factor = .635

Primary fuel = NATURAL GAS

Number of units for refit = 3

| TECHNOLOGY | # OF UNITS | FUEL/ EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | OTHER O & M k\$ |
| | | | | | k\$ | k\$ | k\$ |
| Natural gas boiler | -- | .800 | 2.97 | .0 | 1548.8 | 208.8 | 535.6 |
| #2 Oil fired boiler | -- | .800 | 4.71 | .0 | 2456.2 | 208.8 | 535.6 |
| #6 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| Micronized coal refit | 3 | .800 | 1.20 | 5448.5 | 625.8 | 440.8 | 935.9 |
| Slagging burner refit | 3 | .800 | 1.20 | 8867.9 | 625.8 | 440.8 | 935.9 |
| Modular FBC refit | 3 | .790 | 1.20 | 10055.0 | 633.7 | 405.3 | 905.2 |
| Stoker firing refit | 3 | .740 | 1.30 | 8072.0 | 732.9 | 630.7 | 923.8 |
| Coal/water slurry | 3 | .750 | 3.00 | 5411.4 | 1668.8 | 405.3 | 802.2 |
| Coal/oil slurry | 3 | .780 | 3.50 | 4453.0 | 1872.0 | 322.9 | 738.2 |
| Low Btu gasifier refit | 3 | .659 | 1.30 | 8971.8 | 823.5 | 374.0 | 1310.5 |
| Packaged shell stoker | 2 | .740 | 1.30 | 7747.4 | 732.9 | 630.7 | 860.1 |
| Packaged shell FBC | 2 | .760 | 1.20 | 7263.5 | 658.7 | 405.3 | 844.0 |
| Field erected stoker | 1 | .780 | 1.30 | 10158.7 | 695.3 | 628.2 | 750.3 |
| Field erected FBC | 1 | .800 | 1.20 | 9245.3 | 625.8 | 470.9 | 744.7 |
| Pulverized coal boiler | 1 | .800 | 1.20 | 11543.5 | 625.8 | 701.0 | 832.7 |
| Circulating FBC | 1 | .810 | 1.20 | 11141.2 | 618.1 | 403.0 | 800.8 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|--|------------------|--|---------------------|------------------------------------|--|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO | PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO |
| | | | k\$ | RATIO | yr | k\$ | RATIO |
| Natural gas boiler | -- | -- | 25,381 | 1.000 | <--- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 34,882 | -- | | | |
| #6 Oil fired boiler | -- | -- | 0 | -- | | | |
| Micronized coal refit | Not applicable because of space limitations | | | | | | |
| Slagging burner refit | Not applicable because of space limitations | | | | | | |
| Modular FBC refit | Not applicable because of space limitations | | | | | | |
| Stoker firing refit | Not applicable because existing boilers were designed for #2 oil | | | | | | |
| Coal/water slurry | 3 | 23,874 | 29,673 | .855 | >31 | 33,147 | .766 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | Not applicable because of space limitations | | | | | | |
| Packaged shell stoker | 2 | 23,688 | 25,473 | .998 | >31 | 29,965 | .847 |
| Packaged shell FBC | 2 | 23,560 | 22,254 | 1.141 | 16.7 | 26,419 | .961 |
| Field erected stoker | 1 | 22,473 | 26,244 | .967 | >31 | 31,931 | .795 |
| Field erected FBC | 1 | 22,382 | 23,400 | 1.085 | 20.8 | 28,562 | .889 |
| Pulverized coal boiler | 1 | 22,382 | 27,879 | .913 | >31 | 34,214 | .742 |
| Circulating FBC | 1 | 22,105 | 24,726 | 1.026 | 26.9 | 30,848 | .823 |

5:04 PM Oct 19, 1988

HILL AFB: 3 X 25 MBtu/hr. FUEL REAL ESCALATION = ZERO

Total steam output = 75.0 MBtu/hr
 Boiler capacity factor = .835
 Number of units for refit = 3
 Hydrated lime price (\$/ton) = 40.00
 Ash disposal price (\$/ton) = 10.00
 Electric price (cents/kWh) = 5.20
 Labor rate (k\$/yr) = 35.00
 Limestone price (\$/ton) = 20.00

FUEL PRICES
 Natural gas price (\$/MBtu) = 2.97
 #2 Oil price (\$/MBtu) = 4.71
 #6 Oil price (\$/MBtu) = .00

COAL PROPERTIES
 R.O.M. Stoker
 Ash fraction = .080 .080
 Sulfur fraction = .006 .006
 HHV (Btu/lb) = 11650. 11000.

FUEL PRICES
 R.O.M. coal (\$/MBtu) = 1.20
 Stoker coal (\$/MBtu) = 1.30
 Coal/H₂O mix (\$/MBtu) = 3.00
 Coal/oil mix (\$/MBtu) = 3.50

OPTIONS
 Soot blower multiplier = 1.0
 Tube bank mod multiplier = 1.0
 Bottom ash pit multiplier = 1.0
 SO₂ control multiplier = 1.0

LIMESTONE/LIME
 Inert fraction = .05

Primary fuel is 3
NATURAL GAS
 1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1986
 Gen infla index (1987 to base yr) = 1.040
 Gas infla index (1988 to base yr) = 1.000
 Oil infla index (1988 to base yr) = 1.000
 Coal infla index (1988 to base yr) = 1.000
 Project start year = 1990
 Project life (yr) = 30
 Depreciation life (yr) = 15
 General inflation rate (I/yr) = 0
 Type of gas escalation = zero
 Type of oil escalation = zero
 Type of coal escalation = zero
 Discount rate (I/yr) = 10
 Rate of return on invest (I/yr) = 17
 Amount of working capital (month) = 2
 Federal income tax rate (I) = 34
 Local prop tax (& insur) rate (I) = 2

| FUEL | TYPE OF FUEL ESCALATION | REAL ESCALATION RATE (I/yr) | | | |
|------|----------------------------|-----------------------------|---------------|---------------|--------------------|
| | | 1988 -1990 | 1990 -1995 | 1995 -2000 | 2000 AND BEYOND |
| Gas | zero | 0 | 0 | 0 | 0 |
| Oil | zero | 0 | 0 | 0 | 0 |
| Coal | zero | 0 | 0 | 0 | 0 |

5:09 PM Oct 19, 1988

MILL AFB: 3 X 25 MBtu/hr. FUEL REAL ESCALATION = ZERO

Total steam output = 75.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .635

Primary fuel = NATURAL GAS

Number of units for refit = 3

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | OTHER O & M k\$ |
| Natural gas boiler | -- | .800 | 2.97 | .0 | 1548.8 | 206.8 | 535.6 |
| #2 Oil fired boiler | -- | .800 | 4.71 | .0 | 2456.2 | 206.8 | 535.6 |
| #6 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .6 | .0 |
| Micronized coal refit | 3 | .800 | 1.20 | 5449.5 | 625.8 | 440.8 | 935.9 |
| Slagging burner refit | 3 | .800 | 1.20 | 8867.9 | 625.8 | 440.8 | 935.9 |
| Modular FBC refit | 3 | .790 | 1.20 | 10055.0 | 633.7 | 405.5 | 905.2 |
| Stoker firing refit | 3 | .746 | 1.30 | 8072.0 | 732.9 | 630.7 | 923.6 |
| Coal/water slurry | 3 | .750 | 3.00 | 5411.4 | 1668.8 | 405.5 | 802.2 |
| Coal/oil slurry | 3 | .780 | 3.50 | 4453.0 | 1972.0 | 322.9 | 738.2 |
| Low Btu gasifier refit | 3 | .659 | 1.30 | 8971.9 | 823.5 | 374.0 | 1310.5 |
| Packaged shell stoker | 2 | .740 | 1.30 | 7747.4 | 732.9 | 630.7 | 860.1 |
| Packaged shell FBC | 2 | .760 | 1.20 | 7263.5 | 658.7 | 405.5 | 844.0 |
| Field erected stoker | 1 | .780 | 1.30 | 10158.7 | 695.3 | 628.2 | 750.3 |
| Field erected FBC | 1 | .800 | 1.20 | 9245.3 | 625.8 | 470.9 | 744.7 |
| Pulverized coal boiler | 1 | .800 | 1.20 | 11543.5 | 625.8 | 701.0 | 802.7 |
| Circulating FBC | 1 | .810 | 1.20 | 11141.2 | 619.1 | 493.0 | 800.8 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | PRIVATE PROJECT | | |
|------------------------|--|------------------|--|---------------------|------------------------------------|--|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO | PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 18,089 | 1.000 | <--- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 25,153 | -- | | | |
| #6 Oil fired boiler | -- | -- | 0 | -- | | | |
| Micronized coal refit | Not applicable because of space limitations | | | | | | |
| Slagging burner refit | Not applicable because of space limitations | | | | | | |
| Modular FBC refit | Not applicable because of space limitations | | | | | | |
| Stoker firing refit | Not applicable because existing boilers were designed for #2 oil | | | | | | |
| Coal/water slurry | 3 | 23,674 | 27,349 | .661 | >31 | 30,757 | .588 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | Not applicable because of space limitations | | | | | | |
| Packaged shell stoker | 2 | 23,688 | 24,453 | .740 | >31 | 28,915 | .628 |
| Packaged shell FBC | 2 | 23,560 | 21,336 | .848 | >31 | 25,475 | .710 |
| Field erected stoker | 1 | 22,473 | 25,276 | .716 | >31 | 30,935 | .585 |
| Field erected FBC | 1 | 22,382 | 22,529 | .803 | >31 | 27,666 | .654 |
| Pulverized coal boiler | 1 | 22,382 | 26,938 | .672 | >31 | 33,318 | .543 |
| Circulating FBC | 1 | 22,105 | 23,865 | .758 | >31 | 29,963 | .604 |

5:09 PM Oct 19, 1988

KELLY AFB: AFLC

1. BACKGROUND

Kelly AFB is located near San Antonio, Texas. The central heating plant (building No. 376) has five water-tube boilers that burn natural gas or No. 2 oil as the backup fuel; 125-psi steam is produced. The yearly average fuel use is about 59 MBtu/h. Boiler efficiency is 79-82%. No boilers were designed for coal. All other boiler plants at Kelly are too small for consideration.

2. HEATING PLANT UNITS

Heating Plant No. 376:

2 x 54.5 MBtu/h, Babcock & Wilcox, 1971
 49.6 MBtu/h, Babcock & Wilcox, 1976
 2 x 50 MBtu/h, Vogt, 1954

3. IDEAL CAPACITY FACTOR ANALYSIS

The ideal capacity factors listed below were calculated from monthly fuel-use data for plant No. 376.

| Fuel input (MBtu/h) | FY 1985 ideal capacity factor |
|---------------------------|--|
| 40 | 0.99 |
| 50 | 0.95 |
| 60 | 0.87 |
| 70 | 0.80 |
| 80 | 0.72 |
| 90 | 0.65 |
| 100 | 0.59 |

4. ENERGY PRICES

FY 1986 Price Data:

Electricity = 5.2¢/kWh
 Natural gas = \$3.88/MBtu

C. H. Guernsey and Co. Survey:

Electricity = 5.1¢/kWh
 Natural gas = \$4.0/MBtu
 Distillate oil = \$5.88/MBtu

5. COAL PROPERTIES AND PRICES

| | Stoker | ROM |
|-------------------------------------|--------------|--------------|
| Origin | Laredo, Tex. | Laredo, Tex. |
| HHV, Btu/lb | 12,900 | 12,300 |
| % Ash | 10-12 | 12 |
| % Sulfur | 1-1.5 | 1.1-5 |
| % Nitrogen | | |
| Ash-softening temperature, °F | 2250 | 2250 |
| Swelling index | 0 | 0 |
| Top size, in. | 1 3/8 | 2 1/2 |
| Bottom size, in. | 1/8 | 0 |
| Fines, % | 10-15 | 15 |
| Grindability index | 28 | 28 |
| Cost at mine, \$/ton | 40 | 35 |
| Delivered cost, \$/ton | 51 | 46 |
| Energy cost, \$/10 ⁶ Btu | 1.98 | 1.87 |

6. ENVIRONMENTAL REGULATIONS

6.1 Air Pollution Emission Limits for New Sources

SO₂. For boilers <100 MBtu/h: 3 lb/MBtu; for boilers >100 MBtu/h: FBC - 90% reduction to meet limit of 1.2 lb/MBtu; emerging technology - 50% reduction to meet limit of 0.6 lb/MBtu.

NO_x. No emission limits for boilers <100 MBtu/h; for boilers >100 MBtu/h: spreader stoker and FBC - 0.6 lb/MBtu; pulverized coal - 0.7 lb/MBtu.

Particulates. For 50 MBtu/h: 0.3 lb/MBtu; for boilers >100 MBtu/h: 0.05 lb/MBtu.

6.2 Coal-Pile Runoff

Limit: Total suspended solids - 50 mg/L.

6.3 Ash Disposal

In most cases, coal ash is classified as nonhazardous solid waste and may be disposed of in an approved sanitary landfill, with approval by the State.

7. OTHER CONSIDERATIONS

None.

8. COAL-CONVERSION PROJECT OUTLOOK

The most likely project would be to refit/replace one boiler unit. Existing boilers were designed for distillate oil and natural gas, which may make refitting an existing boiler for coal-firing quite difficult, unless it is derated.

If one of the 54.5-MBtu/h units were converted to coal and derated to 43.5 MBtu/h output (~54.5 MBtu/h fuel input), the maximum capacity factor based on monthly data would be roughly 91%. If equipment availability is assumed to be 90%, the overall capacity factor would be somewhere near 82%.

8.1 Effect of Environmental Regulations on Selection of Combustion Technologies

SO₂ and NO_x. Any of the combustion technologies being considered could be employed (with 1.5% sulfur coal) without requiring any measure for NO_x or SO₂ reduction because the proposed conversion project is smaller than 100 MBtu/h.

Particulates. Bag filters or electrostatic precipitators would be required to comply with the particulate emission limits.

8.2 Physical Space and Aesthetics

Heating Plant. The existing boiler plant was originally designed for No. 2 oil. There is only space available for installing coal-water-mixture combustion equipment at the existing boiler or for construction of a new boiler at another site on base.

Coal-Handling Equipment. There is no space available for installing dry coal-handling equipment at the existing boiler plant, but there is enough space for installing coal-water-mixture equipment.

Coal Pile. There is no space available for a coal pile at the existing boiler plant, but there is space at another site on base for a coal pile and a new coal-fired boiler.

8.3 Technical Risk of Combustion Technologies

The existing boilers are designed for No. 2 oil- or gas-firing and therefore are only suitable for conversion to coal-water-mixture firing. The technical risk is fairly high because of limited experience with coal-water-mixture firing of No. 2 oil-designed boilers.

9. COGENERATION PROJECT OUTLOOK

The prospects for a coal-fired cogeneration plant appear to be somewhat marginal. The base has a high minimum monthly average electric load, 24 MWe, but the price of electricity is moderate (5.1¢/KWh). Based on the FY 1986 energy-use data, a cogeneration plant with a boiler rating of 68 MBtu/h output and a 5-MWe turbine generator would have an electrical capacity factor of 90% and a peak thermal output of 50 MBtu/h, with a thermal energy capacity factor of about 75% if used as a baseload heating plant. A water-tube boiler with a steam rating of 1450 psia and 950°F would be the most suitable boiler for this cogeneration system.

10. INPUT AND LCC SUMMARY SPREADSHEETS

ONLY APR: 1 X 43.5 MBtu/hr. ECONOMIC PARAMETERS - NOMINAL VALUES

| | |
|--------------------------------------|-------------------------------|
| Total steam output = 43.5 MBtu/hr | |
| Boiler capacity factor = .824 | |
| Number of units for refit = 1 | |
| Hydrated lime price (\$/ton) = 40.00 | COAL PROPERTIES |
| Ash disposal price (\$/ton) = 10.00 | R.O.M. Stoker |
| Electric price (cents/kWh) = 5.10 | Ash fraction = .120 .110 |
| Labor rate (k\$/yr) = 35.00 | Sulfur fraction = .013 .013 |
| Limestone price (\$/ton) = 20.00 | HHV (Btu/lb) = 12300. 12900. |
| FUEL PRICES | FUEL PRICES |
| Natural gas price (\$/MBtu) = 4.00 | R.O.M. coal (\$/MBtu) = 1.87 |
| #2 Oil price (\$/MBtu) = 4.71 | Stoker coal (\$/MBtu) = 1.98 |
| #6 Oil price (\$/MBtu) = .00 | Coal/H2O mix (\$/MBtu) = 3.00 |
| OPTIONS | Coal/oil mix (\$/MBtu) = 3.50 |
| Soot blower multiplier = 1.0 | |
| Tube bank mod multiplier = 1.0 | Primary fuel is 3 |
| Bottom ash pit multiplier = 1.0 | NATURAL GAS |
| SO2 control multiplier = .0 | 1=#6 Oil, 2=#2 Oil, 3=NG |
| LIMESTONE/LIME | |
| Inert fraction = .05 | |

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988
 Gen infla index (1987 to base yr) = 1.040
 Gas infla index (1988 to base yr) = 1.000
 Oil infla index (1988 to base yr) = 1.000
 Coal infla index (1988 to base yr) = 1.000
 Project start year = 1990
 Project life (yr) = 30
 Depreciation life (yr) = 15
 General inflation rate (I/yr) = 0
 Type of gas escalation = egas
 Type of oil escalation = eoil
 Type of coal escalation = ecoal
 Discount rate (I/yr) = 10
 Rate of return on invest (I/yr) = 17
 Amount of working capital (month) = 2
 Federal income tax rate (I) = 34
 Local prop tax (& insur) rate (I) = 2

| | | REAL ESCALATION RATE (I/yr) | | | |
|------|----------------------------|-----------------------------|-------|-------|----------|
| FUEL | TYPE OF FUEL ESCALATION | 1988 | 1990 | 1995 | 2000 AND |
| | | -1990 | -1995 | -2000 | BEYOND |
| Gas | egas | 3.89 | 8.87 | 5.77 | 5.77 |
| Oil | eoil | 4.86 | 7.87 | 4.16 | 4.16 |
| Coal | ecoal | 1.16 | 2.31 | 1.19 | 1.19 |

8:49 AM Oct 20, 1988

KELLY APP: 1 X 43.5 MBtu/hr. ECONOMIC PARAMETERS = NOMINAL VALUES

Total steam output = 43.5 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .826

Primary fuel = NATURAL GAS

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL \$ | ANNUAL COSTS | | |
|------------------------|------------|----------------|--------------------|------------------|--------------|----------------|----------------|
| | | | | | FUEL \$ | MAINT O & M \$ | OTHER O & M \$ |
| Natural gas boiler | -- | .800 | 4.00 | .0 | 1570.0 | 153.2 | 463.4 |
| #2 Oil fired boiler | -- | .800 | 4.71 | .0 | 1848.6 | 153.2 | 463.4 |
| #6 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| Micronized coal refit | 1 | .800 | 1.87 | 2599.2 | 734.0 | 350.2 | 635.9 |
| Slagging burner refit | 1 | .800 | 1.87 | 4341.3 | 734.0 | 350.2 | 635.9 |
| Modular FBC refit | 1 | .790 | 1.87 | 4958.8 | 743.3 | 333.3 | 617.5 |
| Stoker firing refit | 1 | .760 | 1.98 | 2872.6 | 818.0 | 333.3 | 606.0 |
| Coal/water slurry | 1 | .750 | 3.00 | 2620.3 | 1256.0 | 333.3 | 438.0 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2180.8 | 1408.9 | 265.4 | 508.2 |
| Low Btu gasifier refit | 1 | .679 | 1.98 | 3898.5 | 916.2 | 307.4 | 734.8 |
| Packaged shell stoker | 1 | .760 | 1.98 | 3343.0 | 818.0 | 333.3 | 606.0 |
| Packaged shell FBC | 1 | .760 | 1.87 | 4210.3 | 772.6 | 333.3 | 618.3 |
| Field erected stoker | 1 | .800 | 1.98 | 5971.2 | 777.1 | 331.3 | 597.9 |
| Field erected FBC | 1 | .800 | 1.87 | 6545.1 | 734.0 | 387.1 | 617.2 |
| Pulverized coal boiler | 1 | .820 | 1.87 | 6944.2 | 716.1 | 391.1 | 645.2 |
| Circulating FBC | 1 | .810 | 1.87 | 7732.0 | 724.9 | 331.3 | 675.4 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|--|------------------|---|--------------------|------------------------------------|---|--------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT \$ | BENEFIT/COST RATIO | PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT \$ | BENEFIT/COST RATIO |
| Natural gas boiler | -- | -- | 32,548 | 1.000 | ---- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 33,129 | -- | | | |
| #6 Oil fired boiler | -- | -- | 0 | -- | | | |
| Micronized coal refit | Not applicable because of space limitations | | | | | | |
| Slagging burner refit | Not applicable because of space limitations | | | | | | |
| Modular FBC refit | Not applicable because of space limitations | | | | | | |
| Stoker firing refit | Not applicable because existing boiler was designed for #2 oil | | | | | | |
| Coal/water slurry | 1 | 17,019 | 21,071 | 1.545 | 7.3 | 22,943 | 1.419 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | Not applicable because of space limitations | | | | | | |
| Packaged shell stoker | 1 | 16,014 | 18,407 | 1.798 | 5.9 | 20,247 | 1.608 |
| Packaged shell FBC | 1 | 16,795 | 18,495 | 1.760 | 6.8 | 21,067 | 1.545 |
| Field erected stoker | 1 | 15,213 | 19,845 | 1.643 | 8.7 | 23,283 | 1.398 |
| Field erected FBC | 1 | 15,955 | 20,536 | 1.585 | 9.7 | 24,303 | 1.339 |
| Pulverized coal boiler | 1 | 15,400 | 20,953 | 1.553 | 10.2 | 24,928 | 1.306 |
| Circulating FBC | 1 | 15,759 | 21,387 | 1.522 | 11.0 | 25,755 | 1.264 |

KELLY AVE: 1 X 43.5 MBtu/hr. FUEL REAL ESCALATION - AEO 1987

Total steam output = 43.5 MBtu/hr

Boiler capacity factor = .824

Number of units for refit = 1

Hydrated lime price (\$/ton) = 40.00

Ash disposal price (\$/ton) = 10.00

Electric price (cents/kWh) = 5.10

Labor rate (k\$/yr) = 35.00

Limestone price (\$/ton) = 20.00

FUEL PRICES

Natural gas price (\$/MBtu) = 4.00

#2 Oil price (\$/MBtu) = 4.71

#6 Oil price (\$/MBtu) = .00

OPTIONS

Soot blower multiplier = 1.0

Tube bank mod multiplier = 1.0

Bottom ash pit multiplier = 1.0

SO2 control multiplier = .0

LIMESTONE/LIME

Inert fraction = .05

COAL PROPERTIESR.O.M. Stoker

Ash fraction = .120 .110

Sulfur fraction = .013 .013

HHV (Btu/lb) = 12300. 12900.

FUEL PRICES

R.O.M. coal (\$/MBtu) = 1.87

Stoker coal (\$/MBtu) = 1.98

Coal/H2O mix (\$/MBtu) = 3.00

Coal/oil mix (\$/MBtu) = 3.50

Primary fuel is 3

NATURAL GAS

1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988

Gen infla index (1987 to base yr) = 1.040

Gas infla index (1988 to base yr) = 1.000

Oil infla index (1988 to base yr) = 1.000

Coal infla index (1988 to base yr) = 1.000

Project start year = 1990

Project life (yr) = 30

Depreciation life (yr) = 15

General inflation rate (I/yr) = 0

Type of gas escalation = egas

Type of oil escalation = eoil

Type of coal escalation = ecoal

Discount rate (I/yr) = 10

Rate of return on invest (I/yr) = 17

Amount of working capital (month) = 2

Federal income tax rate (I) = 34

Local prop tax (& insur) rate (I) = 2

| | | <u>REAL ESCALATION RATE (I/yr)</u> | | | |
|-------------|---------------------|------------------------------------|-------|-------|----------|
| | <u>TYPE OF FUEL</u> | 1988 | 1990 | 1995 | 2000 AND |
| <u>FUEL</u> | <u>ESCALATION</u> | -1990 | -1995 | -2000 | BEYOND |
| Gas | egas | 2.28 | 4.70 | 5.49 | 2.75 |
| Oil | eoil | .17 | 4.18 | 5.55 | 2.77 |
| Coal | ecoal | 1.46 | 1.76 | 1.61 | .81 |

9:05 AM Oct 20, 1988

KELLY AFB: 1 X 43.5 MBtu/hr. FUEL REAL ESCALATION - APR 1987

Total steam output = 43.5 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .824

Primary fuel = NATURAL GAS

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | OTHER O & M k\$ |
| Natural gas boiler | -- | .800 | 4.00 | .0 | 1570.0 | 153.2 | 463.4 |
| #2 Oil fired boiler | -- | .800 | 4.71 | .0 | 1848.6 | 153.2 | 463.4 |
| #6 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| Micronized coal refit | 1 | .800 | 1.87 | 2599.2 | 734.0 | 350.2 | 635.9 |
| Slagging burner refit | 1 | .800 | 1.87 | 4341.3 | 734.0 | 350.2 | 635.9 |
| Modular FBC refit | 1 | .790 | 1.87 | 4958.8 | 743.3 | 333.3 | 617.5 |
| Stoker firing refit | 1 | .760 | 1.98 | 2872.6 | 818.0 | 333.3 | 606.0 |
| Coal/water slurry | 1 | .750 | 3.00 | 2620.3 | 1256.0 | 333.3 | 538.0 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2180.8 | 1408.9 | 265.4 | 508.2 |
| Low Btu gasifier refit | 1 | .679 | 1.98 | 3895.5 | 916.2 | 307.4 | 734.6 |
| Packaged shell stoker | 1 | .760 | 1.98 | 3343.0 | 818.0 | 333.3 | 606.0 |
| Packaged shell FBC | 1 | .760 | 1.87 | 4210.3 | 772.6 | 333.3 | 618.3 |
| Field erected stoker | 1 | .800 | 1.98 | 5971.2 | 777.1 | 331.3 | 597.9 |
| Field erected FBC | 1 | .800 | 1.87 | 6545.1 | 734.0 | 387.1 | 617.2 |
| Pulverized coal boiler | 1 | .820 | 1.87 | 6944.2 | 716.1 | 391.1 | 645.2 |
| Circulating FBC | 1 | .810 | 1.87 | 7732.0 | 724.9 | 331.3 | 675.4 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|--|------------------|---------------------|---------------------|------------------------------------|---------------------|---------------------|
| | | | LIFE CYCLE COST, | BENEFIT/ COST RATIO | DISCOUNTED PAYBACK PERIOD, yr | LIFE CYCLE COST, | BENEFIT/ COST RATIO |
| | | | DISCOUNTED AS SPENT | | | DISCOUNTED AS SPENT | |
| | | | k\$ | | | k\$ | |
| Natural gas boiler | -- | -- | 24,604 | 1.000 | <--- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 26,702 | -- | | | |
| #6 Oil fired boiler | -- | -- | 0 | -- | | | |
| Micronized coal refit | Not applicable because of space limitations | | | | | | |
| Slagging burner refit | Not applicable because of space limitations | | | | | | |
| Modular FBC refit | Not applicable because of space limitations | | | | | | |
| Stoker firing refit | Not applicable because existing boiler was designed for #2 oil | | | | | | |
| Coal/water slurry | 1 | 17,019 | 20,871 | 1.179 | 11.7 | 22,738 | 1.082 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | Not applicable because of space limitations | | | | | | |
| Packaged shell stoker | 1 | 16,014 | 17,977 | 1.369 | 7.9 | 20,113 | 1.223 |
| Packaged shell FBC | 1 | 16,795 | 18,372 | 1.339 | 9.2 | 20,941 | 1.175 |
| Field erected stoker | 1 | 15,213 | 19,692 | 1.249 | 12.3 | 23,155 | 1.063 |
| Field erected FBC | 1 | 15,955 | 20,419 | 1.205 | 13.9 | 24,183 | 1.017 |
| Pulverized coal boiler | 1 | 15,566 | 20,839 | 1.181 | 15.0 | 24,809 | .992 |
| Circulating FBC | 1 | 15,758 | 21,272 | 1.157 | 16.4 | 25,637 | .960 |

KELLY AFB: 1 X 43.5 MBtu/hr. FUEL REAL ESCALATION = ZERO

Total steam output = 43.5 MBtu/hr

Boiler capacity factor = .824

Number of units for refit = 1

Hydrated lime price (\$/ton) = 40.00

Ash disposal price (\$/ton) = 10.00

Electric price (cents/kWh) = 5.10

Labor rate (\$/yr) = 35.00

Limestone price (\$/ton) = 20.00

FUEL PRICES

Natural gas price (\$/MBtu) = 4.00

#2 Oil price (\$/MBtu) = 4.71

#6 Oil price (\$/MBtu) = .00

OPTIONS

Soot blower multiplier = 1.0

Tube bank mod multiplier = 1.0

Bottom ash pit multiplier = 1.0

SO2 control multiplier = .0

LIMESTONE/LIME

Inert fraction = .05

COAL PROPERTIESR.O.M. Stoker

Ash fraction = .120 .110

Sulfur fraction = .013 .013

MHV (Btu/lb) = 12300. 12000.

FUEL PRICES

R.O.M. coal (\$/MBtu) = 1.87

Stoker coal (\$/MBtu) = 1.98

Coal/H2O mix (\$/MBtu) = 3.00

Coal/oil mix (\$/MBtu) = 3.50

Primary fuel is 3

NATURAL GAS

1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988

Gen infla index (1987 to base yr) = 1.040

Gas infla index (1988 to base yr) = 1.000

Oil infla index (1988 to base yr) = 1.000

Coal infla index (1988 to base yr) = 1.000

Project start year = 1990

Project life (yr) = 30

Depreciation life (yr) = 15

General inflation rate (I/yr) = 0

Type of gas escalation = zero

Type of oil escalation = zero

Type of coal escalation = zero

Discount rate (I/yr) = 10

Rate of return on invest (I/yr) = 17

Amount of working capital (month) = 2

Federal income tax rate (I) = 34

Local prop tax (& insur) rate (I) = 2

| FUEL | TYPE OF FUEL ESCALATION | REAL ESCALATION RATE (I/yr) | | | |
|------|----------------------------|-----------------------------|-------|-------|----------|
| | | 1988 | 1990 | 1995 | 2000 AND |
| | | -1990 | -1995 | -2000 | BEYOND |
| Gas | zero | 0 | 0 | 0 | 0 |
| Oil | zero | 0 | 0 | 0 | 0 |
| Coal | zero | 0 | 0 | 0 | 0 |

9:10 AM Oct 20, 1988

KELLY APR: 1 X 43.5 MBtu/hr. FUEL REAL ESCALATION = ZERO

Total steam output = 43.5 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .824

Primary fuel = NATURAL GAS

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | OTHER O & M k\$ |
| Natural gas boiler | -- | .800 | 4.00 | .0 | 1570.0 | 153.2 | 463.4 |
| #2 Oil fired boiler | -- | .800 | 4.71 | .0 | 1848.6 | 153.2 | 463.4 |
| #6 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| Micronized coal refit | 1 | .800 | 1.87 | 2599.2 | 734.0 | 350.2 | 635.9 |
| Slagging burner refit | 1 | .800 | 1.87 | 4341.3 | 734.0 | 350.2 | 635.9 |
| Modular FBC refit | 1 | .790 | 1.87 | 4958.8 | 743.3 | 333.3 | 617.5 |
| Stoker firing refit | 1 | .760 | 1.98 | 2872.6 | 818.0 | 333.3 | 606.0 |
| Coal/water slurry | 1 | .750 | 3.00 | 2620.3 | 1256.0 | 333.3 | 538.0 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2180.8 | 1408.9 | 265.4 | 508.2 |
| Low Btu gasifier refit | 1 | .870 | 1.98 | 3890.5 | 916.2 | 307.4 | 734.8 |
| Packaged shell stoker | 1 | .760 | 1.98 | 3343.0 | 818.0 | 333.3 | 606.0 |
| Packaged shell FBC | 1 | .760 | 1.87 | 4210.3 | 772.6 | 333.3 | 618.3 |
| Field erected stoker | 1 | .800 | 1.98 | 5971.2 | 777.1 | 331.3 | 597.9 |
| Field erected FBC | 1 | .800 | 1.87 | 6545.1 | 734.0 | 387.1 | 617.2 |
| Pulverized coal boiler | 1 | .820 | 1.87 | 6944.2 | 716.1 | 391.1 | 645.2 |
| Circulating FBC | 1 | .810 | 1.87 | 7732.0 | 724.9 | 331.3 | 675.4 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|--|------------------|--|---------------------|------------------------------------|-------------------------|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO | PAYBACK PERIOD, yr | DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 17,212 | 1.000 | <--- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 19,383 | -- | | | |
| #6 Oil fired boiler | -- | -- | 0 | -- | | | |
| Micronized coal refit | Not applicable because of space limitations | | | | | | |
| Slagging burner refit | Not applicable because of space limitations | | | | | | |
| Modular FBC refit | Not applicable because of space limitations | | | | | | |
| Stoker firing refit | Not applicable because existing boiler was designed for #2 oil | | | | | | |
| Coal/water slurry | 1 | 17,019 | 19,122 | .900 | >31 | 20,939 | .822 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | Not applicable because of space limitations | | | | | | |
| Packaged shell stoker | 1 | 16,014 | 16,838 | 1.022 | 19.3 | 18,941 | .909 |
| Packaged shell FBC | 1 | 16,795 | 17,296 | .995 | >31 | 19,435 | .868 |
| Field erected stoker | 1 | 15,213 | 18,610 | .925 | >31 | 22,042 | .781 |
| Field erected FBC | 1 | 15,955 | 19,397 | .887 | >31 | 23,132 | .744 |
| Pulverized coal boiler | 1 | 15,566 | 19,842 | .867 | >31 | 23,783 | .724 |
| Circulating FBC | 1 | 15,758 | 20,262 | .849 | >31 | 24,599 | .700 |

ROBINS AFB: AFLC

1. BACKGROUND

Robins Air Force base is located near Warner Robins, Georgia. There are two major heating plants on the base, but only the larger plant (building No. 177) should be considered for coal conversion. The B&W and Wicks units (see list below) were originally designed for coal. In 1967, the coal-burning boilers were converted to burn gas with distillate oil as backup. The yearly average fuel use at plant No. 177 is about 190 MBtu/h. Heat plant No. 177 produces 125 psi steam, and boiler efficiencies range from about 69% at low loads to 78% at full load. No coal-handling equipment still remains.

2. HEATING PLANT UNITS

Heating Plant No. 177:

2 x 98 MBtu/h, Erie City, 1966
 2 x 54 MBtu/h, Babcock & Wilcox, 1953
 54 MBtu/h, Wicks, 1954
 5 MBtu/h, Superior (oil only), 1977

Heating Plant No. 644:

24 MBtu/h, Erie City, 1966
 2 x 24 MBtu/h, Trane, 1975
 21 MBtu/h, Babcock & Wilcox, 1955

3. IDEAL CAPACITY FACTOR ANALYSIS

The maximum possible capacity factors listed below were calculated from monthly fuel-use data for plant No. 177.

| Fuel input (MBtu/hr) | FY 1985 ideal capacity factor | FY 1986 ideal capacity factor |
|----------------------------|--|--|
| 30 | 0.83 | 1.00 |
| 50 | 0.83 | 1.00 |
| 70 | 0.83 | 0.96 |
| 90 | 0.78 | 0.85 |
| 120 | 0.68 | 0.72 |
| 150 | 0.59 | 0.63 |

4. ENERGY PRICES

FY 1986 Price Data:

| | <u>Year average</u> | <u>End of year</u> |
|-------------|-------------------------|--------------------|
| Distillate | \$5.50/MBtu | \$5.90/MBtu |
| Natural gas | \$3.90/MBtu | \$3.90/MBtu |
| Electric | \$12.96/MBtu = 4.4¢/kWh | 4.4¢/kWh |

Comments from HQ AFLC (11/21/88):

Natural gas = \$3.19/MBtu

5. COAL PROPERTIES AND PRICES

| | <u>Stoker</u> | <u>ROM</u> |
|-------------------------------|---------------|---------------|
| Origin | Benedict, Va. | Benedict, Va. |
| HHV, Btu/lb | 13,790 | 13,790 |
| Ash, % | 4.23 | 4.23 |
| Sulfur, % | 0.79 | 0.79 |
| Nitrogen, % | 1.45 | 1.45 |
| Ash-softening temperature, °F | 2700+ | 2700+ |
| Swelling index | | |
| Top size, in. | | 2 x 0 |
| Bottom size, in. | | 100 mesh |
| Fines, % | | 40 |
| Grindability index | 48 | 48 |
| Cost at mine, \$/ton | 34.00 | 28.00 |
| Delivered cost, \$/ton | 54.85 | 48.85 |
| Energy cost, \$/MBtu | 1.99 | 1.77 |

6. ENVIRONMENTAL REGULATIONS

6.1 Air Pollution Emission Limits for New Sources

The air-quality-control regulations of Georgia require that a fuel-burning plant such as that being considered for Robbins AFB meet federal EPA air emission standards for an attainment area.

SO₂. For boilers >100 MBtu/h: FBC - 90% reduction to meet limit of 1.2 lb/MBtu; emerging technology - 50% reduction to meet limit of 0.6 lb/MBtu.

NO_x. For boilers >100 MBtu/h: spreader stoker and FBC - 0.6 lb/MBtu; pulverized coal - 0.7 lb/MBtu.

Particulates. Regulations pertaining to fly ash and/or other particulate matter from newly (beginning CY 1972) constructed

equipment limit emissions according to the following expression:

$$P = 0.5 \left(\frac{10}{R} \right)^{0.5} \text{ lb/MBtu,}$$

where R = heat input of fuel-burning equipment in MBtu/h.

Therefore, for one 54-MBtu/h boiler at plant No. 177, $P = 0.215$ lb/MBtu.

A state opacity regulation also became effective in 1972, stating that the opacity of the visible emissions be <20% except for one 6-min period per hour of no more than 27% opacity.

6.2 Coal-Pile Runoff

The state of Georgia has adopted EPA federal regulations for coal-pile runoff. The regulations state that the pH of all discharges, except once-through cooling water, shall be within the range of 6.0 to 9.0. The effluent limitation for the point source discharges of coal-pile runoff is 50 mg/L total suspended solids.

6.3 Ash Disposal

The state, as well as the EPA, considers fly ash waste to be nonhazardous. Use of an existing landfill is desirable because only a permit is required. A new site or landfill is costly and requires a long procedure.

7. OTHER CONSIDERATIONS

None.

8. COAL-CONVERSION PROJECT OUTLOOK

The most attractive project would be to refit/replace one of the 54-MBtu/h output (69-MBtu/h fuel input) boiler units, which are coal designed, in plant 177. If a single 54-MBtu/h unit were involved in a project, an overall capacity factor of about 81% would be expected, assuming 90% equipment availability.

8.1 Effect of Environmental Regulations on Selection of Combustion Technologies

SO₂ and NO_x. Any of the combustion technologies being considered could be employed without any SO₂ or NO_x controls because the proposed project is smaller than 100 MBtu/h.

Particulates. Bag filters or electrostatic precipitators would be required.

8.2 Physical Space and Aesthetics

Heating Plant. The existing boiler plant was originally designed for coal. The original coal-combustion equipment has been removed, and there is now only enough space for micronized coal or coal-water-mixture combustion equipment at the existing boiler.

Coal-Handling Equipment. There is limited space available at the existing heating plant so that only micronized coal or coal-water-mixture equipment could probably be installed.

Coal Pile. There is room for a coal pile near the existing boiler plant, so coal could be supplied by truck to a silo at the existing boiler plant or to a new coal-fired boiler plant near the coal pile.

8.3 Technical Risk of Combustion Technologies

The boilers were originally designed for coal. The least technical risk would be for conversion to micronized coal-firing because no SO₂ reduction measures will be required.

9. COGENERATION PROJECT OUTLOOK

The prospects for a coal-fired cogeneration system are poor because of low electric rates and the mild climate that exists at Robbins AFB. Although the base has a sizable minimum monthly average electric load, 15.7 MWe, the price of electricity is only 4.4¢/kWh. The 15.7-MWe minimum monthly load would be met primarily by a coal-fired electric plant sized for about 15 MWe and producing 45 MWh. An 80% cycle efficiency would require a boiler rated at 56 MW. December, January, February, and March have thermal consumption levels exceeding the available thermal capacity. The thermal demands at Robbins AFB remain high enough during the year to result in a high overall thermal load factor of 73% (assuming that the cogeneration plant has a 90% availability).

10. INPUT AND LOG SUMMARY SPREADSHEETS

BOWLINE AFB: 1 X 54 MMTu/hr. ECONOMIC PARAMETERS - NOMINAL VALUES

Total steam output = 54.0 MMTu/hr
 Boiler capacity factor = .808
 Number of units for refit = 1
 Hydrated lime price (\$/ton) = 40.00
 Ash disposal price (\$/ton) = 10.00
 Electric price (cents/kWh) = 4.40
 Labor rate (\$/hr) = 35.00
 Limestone price (\$/ton) = 20.00

FUEL PRICES

Natural gas price (\$/MMtu) = 3.19
 #2 Oil price (\$/MMtu) = 4.71
 #6 Oil price (\$/MMtu) = .00

COAL PROPERTIES

| | R.O.M. | Stoker |
|-----------------|--------|--------|
| Ash fraction | .042 | .042 |
| Sulfur fraction | .008 | .008 |
| MMV (Btu/lb) | 13800. | 13800. |

FUEL PRICES

R.O.M. coal (\$/MMtu) = 1.77
 Stoker coal (\$/MMtu) = 1.99
 Coal/H₂O mix (\$/MMtu) = 3.00
 Coal/oil mix (\$/MMtu) = 3.50

OPTIONS

Soot blower multiplier = .0
 Tube bank mod multiplier = .0
 Bottom ash pit multiplier = 1.0
 SO₂ control multiplier = .0

LIMESTONE/LIME

Inert fraction = .05

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988
 Gen infla index (1987 to base yr) = 1.040
 Gas infla index (1988 to base yr) = 1.000
 Oil infla index (1988 to base yr) = 1.000
 Coal infla index (1988 to base yr) = 1.000
 Project start year = 1990
 Project life (yr) = 30
 Depreciation life (yr) = 15
 General inflation rate (I/yr) = 0
 Type of gas escalation = egas
 Type of oil escalation = eoil
 Type of coal escalation = ecoal
 Discount rate (I/yr) = 10
 Rate of return on invest (I/yr) = 17
 Amount of working capital (month) = 2
 Federal income tax rate (I) = 34
 Local prop tax (& insur) rate (I) = 2

Primary fuel is 3

NATURAL GAS

1-#6 Oil, 2-#2 Oil, 3-NG

| | | REAL ESCALATION RATE (I/yr) | | | |
|------|----------------------------|-----------------------------|-------|-------|--------------------|
| FUEL | TYPE OF FUEL ESCALATION | 1988 | 1990 | 1995 | 2000 AND BEYOND |
| | | -1990 | -1995 | -2000 | |
| Gas | egas | 3.89 | 8.67 | 5.77 | 5.77 |
| Oil | eoil | 4.86 | 7.67 | 4.16 | 4.16 |
| Coal | ecoal | 1.16 | 2.31 | 1.19 | 1.19 |

2:30 PM Jan 4, 1989

BOBINS AFB: 1 X 54 Mtu/hr. ECONOMIC PARAMETERS - NOMINAL VALUES

Total steam output = 54.0 Mtu/hr

Cost base year = 1988

Boiler capacity factor = .806

Primary fuel = NATURAL GAS

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/Mtu | TOTAL CAPITAL \$K | ANNUAL COSTS | | |
|------------------------|------------|-----------------|-------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL \$K | MAINT O & M \$K | OTHER O & M \$K |
| Natural gas boiler | -- | .800 | 3.19 | .0 | 1520.3 | 172.6 | 485.3 |
| #2 Oil fired boiler | -- | .800 | 4.71 | .0 | 2244.1 | 172.6 | 485.3 |
| #6 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| Micronized coal refit | 1 | .800 | 1.77 | 2546.7 | 843.6 | 378.6 | 649.3 |
| Slagging burner refit | 1 | .800 | 1.77 | 4521.4 | 843.6 | 378.6 | 649.3 |
| Modular FBC refit | 1 | .780 | 1.77 | 5220.0 | 854.2 | 360.3 | 629.8 |
| Stoker firing refit | 1 | .780 | 1.89 | 3063.9 | 928.3 | 360.3 | 620.1 |
| Coal/water slurry | 1 | .750 | 3.00 | 2272.1 | 1525.1 | 360.3 | 546.3 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2043.6 | 1710.8 | 286.9 | 523.3 |
| Low Btu gasifier refit | 1 | .679 | 1.89 | 4280.9 | 1118.1 | 332.3 | 744.0 |
| Packaged shell stoker | 2 | .780 | 1.89 | 4805.5 | 998.3 | 360.3 | 710.8 |
| Packaged shell FBC | 2 | .780 | 1.77 | 5818.1 | 888.0 | 360.3 | 720.9 |
| Field erected stoker | 1 | .800 | 1.89 | 6809.0 | 948.4 | 358.1 | 612.0 |
| Field erected FBC | 1 | .800 | 1.77 | 7481.8 | 843.6 | 418.4 | 629.7 |
| Pulverized coal boiler | 1 | .820 | 1.77 | 7928.3 | 823.0 | 422.8 | 659.0 |
| Circulating FBC | 1 | .810 | 1.77 | 8915.1 | 833.1 | 358.1 | 690.5 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|---|------------------|--|---------------------|------------------------------------|--|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT \$K | BENEFIT/ COST RATIO | DISCOUNTED PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT \$K | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 32,020 | 1.000 | <--- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 39,504 | -- | | | |
| #6 Oil fired boiler | -- | -- | 0 | -- | | | |
| Micronized coal refit | 1 | 17,268 | 18,429 | 1.737 | 5.6 | 20,191 | 1.586 |
| Slagging burner refit | Not applicable because of space limitations | | | | | | |
| Modular FBC refit | Not applicable because of space limitations | | | | | | |
| Stoker firing refit | Not applicable because of space limitations | | | | | | |
| Coal/water slurry | 1 | 18,419 | 23,604 | 1.357 | 10.3 | 25,378 | 1.262 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | Not applicable because of space limitations | | | | | | |
| Packaged shell stoker | 2 | 18,176 | 21,892 | 1.463 | 10.0 | 24,754 | 1.294 |
| Packaged shell FBC | 2 | 18,176 | 21,776 | 1.470 | 10.6 | 25,127 | 1.274 |
| Field erected stoker | 1 | 17,268 | 22,458 | 1.426 | 11.9 | 26,407 | 1.213 |
| Field erected FBC | 1 | 17,268 | 22,712 | 1.410 | 12.5 | 26,996 | 1.186 |
| Pulverized coal boiler | 1 | 16,847 | 23,156 | 1.383 | 13.2 | 27,670 | 1.157 |
| Circulating FBC | 1 | 17,054 | 23,733 | 1.349 | 14.3 | 28,744 | 1.114 |

NOBIES AFE: 1 X 54 MBtu/hr. FUEL REAL ESCALATION ~ AEO 1997

Total steam output = 54.0 MBtu/hr

Boiler capacity factor = .806

Number of units for refit = 1

Hydrated lime price (\$/ton) = 40.00

Ash disposal price (\$/ton) = 10.00

Electric price (cents/kWh) = 4.40

Labor rate (k\$/yr) = 35.00

Limestone price (\$/ton) = 20.00

FUEL PRICES

Natural gas price (\$/MBtu) = 3.19

#2 Oil price (\$/MBtu) = 4.71

#6 Oil price (\$/MBtu) = .00

OPTIONS

Soot blower multiplier = .0

Tube bank mod multiplier = .0

Bottom ash pit multiplier = 1.0

SO2 control multiplier = .0

LIMESTONE/LIME

Inert fraction = .03

COAL PROPERTY/ESR.O.M. Stoker

Ash fraction = .042 .042

Sulfur fraction = .008 .008

HHV (Btu/lb) = 13800. 13800.

FUEL PRICES

R.O.M. coal (\$/MBtu) = 1.77

Stoker coal (\$/MBtu) = 1.89

Coal/H2O mix (C/MBtu) = 3.00

Coal/oil mix (\$/MBtu) = 3.50

Primary fuel is 3

NATURAL GAS

1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988

Gen infla index (1987 to base yr) = 1.040

Gas infla index (1988 to base yr) = 1.030

Oil infla index (1988 to base yr) = 1.000

Coal infla index (1988 to base yr) = 1.000

Project start year = 1990

Project life (yr) = 30

Depreciation life (yr) = 15

General inflation rate (I/yr) = 0

Type of gas escalation = egas

Type of oil escalation = eoil

Type of coal escalation = ecoal

Discount rate (I/yr) = 10

Rate of return on invest (I/yr) = 17

Amount of working capital (month) = 2

Federal income tax rate (I) = 34

Local prop tax (& insur) rate (I) = 2

| FUEL | TYPE OF FUEL ESCALATION | REAL ESCALATION RATE (I/yr) | | | |
|------|----------------------------|-----------------------------|---------------|---------------|--------------------|
| | | 1988 -1990 | 1990 -1995 | 1995 -2000 | 2000 AND BEYOND |
| Gas | egas | 2.28 | 4.70 | 5.48 | 2.75 |
| Oil | eoil | .17 | 4.16 | 5.55 | 2.77 |
| Coal | ecoal | 1.46 | 1.76 | 1.61 | .81 |

1:57 PM Jan 11, 1989

POSITIVE: 2 X 34 MBtu/hr. FUEL REAL ESCALATION = AEO 1987

Total steam output = 34.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .806

Primary fuel = NATURAL GAS

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL \$K | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL \$K | MAINT O & M \$K | OTHER O & M \$K |
| Natural gas boiler | -- | .800 | 3.18 | .0 | 1520.3 | 172.6 | 485.3 |
| #2 Oil fired boiler | -- | .800 | 4.71 | .0 | 2244.7 | 172.6 | 485.3 |
| #6 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| Micronized coal refit | 1 | .800 | 1.77 | 2546.7 | 843.6 | 378.6 | 649.3 |
| Slagging burner refit | 1 | .800 | 1.77 | 4521.4 | 843.6 | 378.6 | 649.3 |
| Modular FBC refit | 1 | .790 | 1.77 | 5220.0 | 854.2 | 360.3 | 629.8 |
| Stoker firing refit | 1 | .760 | 1.09 | 3063.9 | 698.3 | 360.3 | 620.1 |
| Coal/water slurry | 1 | .750 | 3.06 | 2272.3 | 1525.1 | 360.3 | 546.3 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2043.6 | 1710.8 | 286.9 | 523.3 |
| Low Btu gasifier refit | 1 | .678 | 1.96 | 4260.0 | 1118.1 | 372.3 | 754.9 |
| Packaged shell stoker | 2 | .760 | 1.09 | 4605.5 | 698.3 | 360.3 | 710.6 |
| Packaged shell FBC | 2 | .780 | 1.77 | 5618.1 | 888.0 | 360.3 | 720.9 |
| Field erected stoker | 1 | .800 | 1.09 | 6809.0 | 948.4 | 358.1 | 612.0 |
| Field erected FBC | 1 | .800 | 1.77 | 7481.8 | 843.6 | 418.4 | 629.7 |
| Pulverized coal boiler | 1 | .820 | 1.77 | 7028.3 | 823.0 | 422.8 | 659.0 |
| Circulating FBC | 1 | .810 | 1.77 | 8915.1 | 833.1 | 358.1 | 690.5 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|---|------------------|--|---------------------|------------------------------------|--|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT \$K | BENEFIT/ COST RATIO | DISCOUNTED PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT \$K | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 24,327 | 1.000 | <--- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 31,699 | -- | | | |
| #6 Oil fired boiler | -- | -- | 0 | -- | | | |
| Micronized coal refit | 1 | 17,268 | 18,295 | 1.330 | 7.7 | 20,053 | 1.213 |
| Slagging burner refit | Not applicable because of space limitations | | | | | | |
| Modular FBC refit | Not applicable because of space limitations | | | | | | |
| Stoker firing refit | Not applicable because of space limitations | | | | | | |
| Coal/water slurry | 1 | 18,419 | 23,361 | 1.041 | 22.3 | 25,129 | .968 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | Not applicable because of space limitations | | | | | | |
| Packaged shell stoker | 2 | 13,176 | 21,734 | 1.119 | 16.5 | 24,590 | .989 |
| Packaged shell FBC | 2 | 18,176 | 21,635 | 1.124 | 16.8 | 24,982 | .974 |
| Field erected stoker | 1 | 17,268 | 22,307 | 1.091 | 19.6 | 26,252 | .927 |
| Field erected FBC | 1 | 17,268 | 22,577 | 1.077 | 20.9 | 26,858 | .906 |
| Pulverized coal boiler | 1 | 16,847 | 23,025 | 1.057 | 22.9 | 27,535 | .863 |
| Circulating FBC | 1 | 17,054 | 23,601 | 1.031 | 26.1 | 28,607 | .850 |

1:57 PM Jan 11, 1989

BOILER AVE: 1 X 54 MBtu/hr. FUEL REAL ESCALATION = ZERO

Total steam output ~ 54.0 MBtu/hr

Boiler capacity factor ~ .806

Number of units for refit ~ 1

Hydrated lime price (\$/ton) ~ 40.00

Ash disposal price (\$/ton) ~ 10.00

Electric price (cents/kWh) ~ 4.40

Labor rate (k\$/yr) ~ 35.00

Limestone price (\$/ton) ~ 20.00

FUEL PRICES

Natural gas price (\$/MBtu) ~ 3.19

#2 Oil price (\$/MBtu) ~ 4.71

#6 Oil price (\$/MBtu) ~ .00

OPTIONS

Soot blower multiplier ~ .0

Tube bank mod multiplier ~ .0

Bottom ash pit multiplier ~ 1.0

SO2 control multiplier ~ .0

LIMESTONE/LIME

Inert fraction ~ .05

COAL PROPERTIESR.O.M. Stoker

Ash fraction ~ .042 .042

Sulfur fraction ~ .008 .008

HHV (Btu/lb) ~ 13600. 13600.

FUEL PRICES

R.O.M. coal (\$/MBtu) ~ 1.77

Stoker coal (\$/MBtu) ~ 1.99

Coal/H2O mix (\$/MBtu) ~ 3.00

Coal/oil mix (\$/MBtu) ~ 3.50

Primary fuel is 3

NATURAL GAS

1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year ~ 1988

Gen infla index (1987 to base yr) ~ 1.040

Gas infla index (1988 to base yr) ~ 1.000

Oil infla index (1988 to base yr) ~ 1.000

Coal infla index (1988 to base yr) ~ 1.000

Project start year ~ 1990

Project life (yr) ~ 30

Depreciation life (yr) ~ 15

General inflation rate (I/yr) ~ 0

Type of gas escalation ~ zero

Type of oil escalation ~ zero

Type of coal escalation ~ zero

Discount rate (I/yr) ~ 10

Rate of return on invest (I/yr) ~ 17

Amount of working capital (month) ~ 2

Federal income tax rate (I) ~ 34

Local prop tax (& insur) rate (I) ~ 2

| | | <u>REAL ESCALATION RATE (I/yr)</u> | | | |
|-------------|---------------------|------------------------------------|--------------|--------------|-----------------|
| | <u>TYPE OF FUEL</u> | <u>1988</u> | <u>1990</u> | <u>1995</u> | <u>2000 AND</u> |
| <u>FUEL</u> | <u>ESCALATION</u> | <u>-1990</u> | <u>-1995</u> | <u>-2000</u> | <u>BEYOND</u> |
| Gas | zero | 0 | 0 | 0 | 0 |
| Oil | zero | 0 | 0 | 0 | 0 |
| Coal | zero | 0 | 0 | 0 | 0 |

2:02 PM Jan 11, 1989

ROBINS AFB: 1 X 54 MBtu/hr. FUEL REAL ESCALATION = ZERO

Total steam output = 54.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .806

Primary fuel = NATURAL GAS

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | OTHER O & M k\$ |
| Natural gas boiler | -- | .800 | 3.19 | .0 | 1520.3 | 172.6 | 485.3 |
| #2 Oil fired boiler | -- | .800 | 4.71 | .0 | 2244.7 | 172.6 | 485.3 |
| #6 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| Micronized coal refit | 1 | .800 | 1.77 | 2546.7 | 843.6 | 378.6 | 649.3 |
| Slagging burner refit | 1 | .800 | 1.77 | 4521.4 | 843.6 | 378.6 | 649.3 |
| Modular FBC refit | 1 | .790 | 1.77 | 5220.0 | 854.2 | 360.3 | 629.8 |
| Stoker firing refit | 1 | .760 | 1.99 | 3063.9 | 998.3 | 360.3 | 620.1 |
| Coal/water slurry | 1 | .750 | 3.00 | 2272.1 | 1525.1 | 360.3 | 548.3 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2043.6 | 1710.8 | 286.9 | 523.3 |
| Low Btu gasifier refit | 1 | .679 | 1.99 | 4260.9 | 1118.1 | 332.3 | 754.9 |
| Packaged shell stoker | 2 | .760 | 1.99 | 4805.5 | 998.3 | 360.3 | 710.8 |
| Packaged shell FBC | 2 | .760 | 1.77 | 5618.1 | 888.0 | 360.3 | 720.9 |
| Field erected stoker | 1 | .800 | 1.99 | 6809.0 | 948.4 | 358.1 | 612.0 |
| Field erected FBC | 1 | .800 | 1.77 | 7481.8 | 843.6 | 418.4 | 629.7 |
| Pulverized coal boiler | 1 | .820 | 1.77 | 7928.3 | 823.0 | 422.8 | 659.0 |
| Circulating FBC | 1 | .810 | 1.77 | 8915.1 | 833.1 | 358.1 | 690.5 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|---|------------------|--|---------------------|------------------------------------|-------------------------|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO | PAYBACK PERIOD, yr | DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 17,169 | 1.000 | <--- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 22,813 | -- | | | |
| #6 Oil fired boiler | -- | -- | 0 | -- | | | |
| Micronized coal refit | 1 | 17,268 | 17,120 | 1.003 | 26.0 | 18,844 | .911 |
| Slagging burner refit | Not applicable because of space limitations | | | | | | |
| Modular FBC refit | Not applicable because of space limitations | | | | | | |
| Stoker firing refit | Not applicable because of space limitations | | | | | | |
| Coal/water slurry | 1 | 18,419 | 21,237 | .808 | >31 | 22,945 | .748 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | Not applicable because of space limitations | | | | | | |
| Packaged shell stoker | 2 | 18,176 | 20,343 | .844 | >31 | 23,161 | .741 |
| Packaged shell FBC | 2 | 18,176 | 20,398 | .842 | >31 | 23,710 | .724 |
| Field erected stoker | 1 | 17,268 | 20,986 | .818 | >31 | 24,894 | .690 |
| Field erected FBC | 1 | 17,268 | 21,403 | .802 | >31 | 25,650 | .669 |
| Pulverized coal boiler | 1 | 16,847 | 21,879 | .785 | >31 | 26,357 | .651 |
| Circulating FBC | 1 | 17,054 | 22,440 | .765 | >31 | 27,414 | .626 |

TINKER AFB: AFLC

1. BACKGROUND

Tinker is near Oklahoma City, Oklahoma. The available information for Tinker is poor, and it was not considered in the C. H. Guernsey and Co. survey. There are two boiler plants at Tinker AFB that are large enough for some consideration. The heating plant in building No. 3001 is the largest of these, with a yearly average fuel use of roughly 150 MBtu/h. The heating plant in building No. 208 appears to use a year-round average of about 75 MBtu/h of fuel. Natural-gas-firing is used with distillate oil as the secondary fuel. No boilers at the base were designed for coal burning. Only plant No. 3001 was considered in the LCC analysis.

2. HEATING PLANT UNITS

Heating Plant No. 3001:

3 x 97 MBtu/h, Riley Stoker, 1942

Heating Plant No. 208:

4 x 41 MBtu/h, Wickes, 1942

3. IDEAL CAPACITY FACTOR ANALYSIS

The ideal capacity factors listed below were calculated from monthly fuel-use data for plant No. 3001.

| Fuel input (MBtu/h) | FY 1986 ideal capacity factor |
|---------------------------|--|
| 100 | 1.00 |
| 120 | 0.99 |
| 140 | 0.94 |
| 160 | 0.87 |
| 180 | 0.82 |
| 200 | 0.76 |
| 220 | 0.70 |

4. ENERGY PRICES

FY 1986 Price Data:

Electricity = \$14/MBtu = 4.8¢/kWh
Natural gas = \$2.85/MBtu

Note: Gas prices dropped during FY 1986 and apparently were near \$2.0/MBtu in the latter portion of the year.

5. COAL PROPERTIES AND PRICES

| | Stoker | ROM |
|-------------------------------------|--------------|--------------------|
| Origin | | McCallister, Okla. |
| HHV, Btu/lb | 12,800 | 12,800 |
| % Ash | 6-7 | 6-7 |
| % Sulfur | 0.77 | 0.77 |
| % Nitrogen | | |
| Ash-softening temperature, °F | | 2080 |
| Swelling index | | 3.5-5 |
| Top size, in. | | 2 |
| Bottom size, in. | | 0 |
| Fines, % | | |
| Grindability index | | 55 |
| Cost at mine, \$/ton | 43 (assumed) | 35 |
| Delivered cost, \$/ton | 51 | 43 |
| Energy cost, \$/10 ⁶ Btu | 1.99 | 1.68 |

6. ENVIRONMENTAL REGULATIONS

6.1 Air Pollution Emission Limits for New Sources

SO₂. For boilers <100 MBtu/h: 1.2 lb/MBtu; for boilers >100 MBtu/h: FBC - 90% reduction to meet limit of 1.2 lb/MBtu; emerging technology - 50% reduction to meet limit of 0.6 lb/MBtu.

NO_x. No emission limits for boilers <100 MBtu/h; for boilers >100 MBtu/h: spreader stoker and FBC - 0.6 lb/MBtu; pulverized coal - 0.7 lb/MBtu.

Particulates. For 99 MBtu/h: 0.3 lb/MBtu; for boilers >100 MBtu/h: 0.05 lb/MBtu.

6.2 Coal-Pile Runoff

Limit: Total suspended solids - 50 mg/L, pH of 6.0-9.0.

6.3 Ash Disposal

The ash will have to be analyzed to determine if it is hazardous. If nonhazardous, the ash may be disposed of in an existing or new landfill that has a lining of 3 ft of clay with a bottom that is at least 5 ft above groundwater.

7. OTHER CONSIDERATIONS

The boilers in heating plant No. 3001 were identified for upgrading in 1982.

8. COAL-CONVERSION PROJECT OUTLOOK

Tinker may be a poor candidate according to the AFLC MAJCOM. Tinker does seem to be a large fuel user, however, and it is not clear what would make it a poor candidate. Low gas prices make coal unattractive at this time.

A likely project would be to refit or replace two of the 97-MBtu/h units in plant No. 3001. The boilers would have to be derated to 75 MBtu/h output each (-188 MBtu/h total fuel input) because they were originally designed for No. 2 oil. An overall capacity factor of 71% is expected, assuming 90% availability.

8.1 Effect of Environmental Regulations on Selection of Combustion Technologies

SO₂. The SO₂ emission limits will require the use of low sulfur coal or SO₂ reduction measures with high-sulfur coal.

NO_x. No special NO_x reduction measures will be required for any of the combustion technologies.

Particulates. Bag filters or electrostatic precipitators would be required to comply with the particulate emission limits.

8.2 Physical Space and Aesthetics

Heating Plant. The existing boiler plant was originally designed for No. 2 oil. There is only space available for installing coal-water-mixture combustion equipment at the existing boiler.

Coal-Handling Equipment. There is no information on the space available at the existing plant, but it is probable that there is not enough space available for installing dry coal-handling equipment. There should be adequate space available for installing coal-water-mixture equipment.

Coal Pile. There is no information as to how much space is available for a coal pile at the existing boiler plant.

8.3 Technical Risk of Combustion Technologies

The existing boilers are designed for No. 2 oil- or gas-firing and therefore are only suitable for conversion to coal-water-mixture firing. The technical risk is only moderate because the boilers would be derated.

9. COGENERATION PROJECT OUTLOOK

The prospects for a coal-fired cogeneration system appear to be somewhat marginal. The base has a high minimum monthly average electric load, 26 MWe, but the price of electricity is moderate (4.8¢/kWh). Based on the FY 1986 energy-use data, a cogeneration plant with a boiler rating of 180-MBtu/h output and a 13-MWe turbine generator would have an electrical power capacity factor of 90% and a peak thermal output of 135 MBtu/h with a thermal energy capacity factor of about 90% if used as a baseload heating plant. A water-tube boiler with a steam rating of 1450 psia and 950°F would be the most suitable boiler for this cogeneration system.

10. INPUT AND LCC SUMMARY SPREADSHEETS

TICKER AFB: 2 X 75 MBtu/hr. ECONOMIC PARAMETERS - NOMINAL VALUES

Total steam output = 150.0 MBtu/hr
 Boiler capacity factor = .712
 Number of units for refit = 2
 Hydrated lime price (\$/ton) = 40.00
 Ash disposal price (\$/ton) = 10.00
 Electric price (cents/kWh) = 4.80
 Labor rate (k\$/yr) = 35.00
 Limestone price (\$/ton) = 20.00

FUEL PRICES
 Natural gas price (\$/MBtu) = 2.85
 #2 Oil price (\$/MBtu) = 4.71
 #6 Oil price (\$/MBtu) = .00

OPTIONS
 Soot blower multiplier = 1.0
 Tube bank mod multiplier = 1.0
 Bottom ash pit multiplier = 1.0
 SO2 control multiplier = 1.0

LIMESTONE/LIME
 Inert fraction = .05

COAL PROPERTIES

| | R.O.M. | Stoker |
|-----------------|--------|--------|
| Ash fraction | .065 | .065 |
| Sulfur fraction | .008 | .008 |
| HHV (Btu/lb) | 12800. | 12800. |

FUEL PRICES
 R.O.M. coal (\$/MBtu) = 1.68
 Stoker coal (\$/MBtu) = 1.99
 Coal/H2O mix (\$/MBtu) = 3.00
 Coal/oil mix (\$/MBtu) = 3.50

Primary fuel is 3
 NATURAL GAS
 1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988
 Gen infla index (1987 to base yr) = 1.040
 Gas infla index (1988 to base yr) = 1.000
 Oil infla index (1988 to base yr) = 1.000
 Coal infla index (1988 to base yr) = 1.000
 Project start year = 1990
 Project life (yr) = 30
 Depreciation life (yr) = 15
 General inflation rate (1/yr) = 0
 Type of gas escalation = egas
 Type of oil escalation = eoil
 Type of coal escalation = ecoal
 Discount rate (1/yr) = 10
 Rate of return on invest (1/yr) = 17
 Amount of working capital (month) = 2
 Federal income tax rate (1) = 34
 Local prop tax (& insur) rate (1) = 2

| | | REAL ESCALATION RATE (1/yr) | | | |
|------|----------------------------|-----------------------------|-------|-------|--------------------|
| FUEL | TYPE OF FUEL ESCALATION | 1988 | 1990 | 1995 | 2000 AND BEYOND |
| | | -1980 | -1995 | -2000 | |
| Gas | egas | 3.69 | 8.87 | 5.77 | 5.77 |
| Oil | eoil | 4.86 | 7.87 | 4.16 | 4.16 |
| Coal | ecoal | 1.16 | 2.31 | 1.19 | 1.19 |

1:11 PM Oct 21, 1988

TIKES AFB: 2 X 75 Mbtu/hr. ECONOMIC PARAMETERS - NOMINAL VALUES

Total steam output = 150.0 Mbtu/hr

Cost base year = 1988

Boiler capacity factor = .712

Primary fuel = NATURAL GAS

Number of units for refit = 2

| TECHNOLOGY | # OF UNITS | FUEL/STEAM EFF | FUEL PRICE \$/Mbtu | TOTAL CAPITAL \$K | ANNUAL COSTS | | |
|------------------------|------------|----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL \$K | MAINT O & M \$K | OTHER O & M \$K |
| Natural gas boiler | -- | .800 | 2.85 | .0 | 3333.0 | 302.7 | 672.7 |
| #2 Oil fired boiler | -- | .800 | 4.71 | .0 | 5508.2 | 302.7 | 672.7 |
| #6 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| Micronized coal refit | 2 | .800 | 1.68 | 6643.9 | 1964.7 | 557.2 | 1180.1 |
| Slagging burner refit | 2 | .800 | 1.68 | 11066.9 | 1964.7 | 557.2 | 1180.1 |
| Modular FBC refit | 2 | .790 | 1.68 | 12597.3 | 1989.6 | 520.4 | 1112.6 |
| Stoker firing refit | 2 | .740 | 1.99 | 10292.7 | 2515.9 | 817.5 | 1143.0 |
| Coal/water slurry | 2 | .750 | 3.00 | 6793.5 | 3742.3 | 520.4 | 1007.8 |
| Coal/oil slurry | 2 | .780 | 3.50 | 5667.4 | 4198.1 | 414.4 | 887.7 |
| Low Btu gasifier refit | 3 | .659 | 1.99 | 13413.2 | 2828.9 | 480.0 | 2019.5 |
| Packaged shell stoker | 3 | .740 | 1.99 | 13237.9 | 2515.9 | 817.5 | 1215.0 |
| Packaged shell FBC | 3 | .760 | 1.68 | 12571.5 | 2068.1 | 520.4 | 1190.1 |
| Field erected stoker | 1 | .760 | 1.99 | 15787.4 | 2386.9 | 814.4 | 1006.9 |
| Field erected FBC | 1 | .800 | 1.68 | 14323.9 | 1964.7 | 604.4 | 1001.8 |
| Pulverized coal boiler | 1 | .800 | 1.68 | 17958.5 | 1964.7 | 907.9 | 1076.6 |
| Circulating FBC | 1 | .810 | 1.68 | 17781.7 | 1940.4 | 517.3 | 1074.5 |

| AIR FORCE PROJECT | | | | | | PRIVATE PROJECT | |
|------------------------|--|------------------|--------------|--------------------|------------------------------------|------------------|--------------------|
| LIFE CYCLE COST, | | | | | | LIFE CYCLE COST, | |
| DISCOUNTED | | | | | | DISCOUNTED | |
| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AS SPENT \$K | BENEFIT/COST RATIO | PAYBACK PERIOD, yr | AS SPENT \$K | BENEFIT/COST RATIO |
| Natural gas boiler | -- | -- | 66,471 | 1.000 | ---- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 91,817 | -- | | | |
| #6 Oil fired boiler | -- | -- | 0 | -- | | | |
| Micronized coal refit | Not applicable because of space limitations | | | | | | |
| Slagging burner refit | Not applicable because of space limitations | | | | | | |
| Modular FBC refit | Not applicable because of space limitations | | | | | | |
| Stoker firing refit | Not applicable because existing boilers were designed for #2 oil | | | | | | |
| Coal/water slurry | 2 | 48,728 | 53,082 | 1.252 | 14.9 | 57,892 | 1.148 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | Not applicable because of space limitations | | | | | | |
| Packaged shell stoker | 3 | 49,386 | 51,221 | 1.298 | 15.0 | 59,114 | 1.124 |
| Packaged shell FBC | 3 | 48,086 | 43,637 | 1.523 | 10.4 | 50,991 | 1.304 |
| Field erected stoker | 1 | 46,853 | 50,474 | 1.317 | 15.0 | 59,586 | 1.116 |
| Field erected FBC | 1 | 45,682 | 43,403 | 1.532 | 10.7 | 51,603 | 1.288 |
| Pulverized coal boiler | 1 | 45,682 | 49,702 | 1.337 | 14.9 | 59,849 | 1.111 |
| Circulating FBC | 1 | 45,118 | 45,805 | 1.451 | 12.6 | 55,745 | 1.192 |

TINDER AVE: 2 X 75 MBtu/hr. FUEL REAL ESCALATION ~ AEO 1987

Total steam output ~ 150.0 MBtu/hr
 Boiler capacity factor ~ .712
 Number of units for refit ~ 2
 Hydrated lime price (\$/ton) ~ 40.00
 Ash disposal price (\$/ton) ~ 10.00
 Electric price (cents/kWh) ~ 4.80
 Labor rate (k\$/yr) ~ 35.00
 Limestone price (\$/ton) ~ 20.00

FUEL PRICES
 Natural gas price (\$/MBtu) ~ 2.85
 #2 Oil price (\$/MBtu) ~ 4.71
 #6 Oil price (\$/MBtu) ~ .00

COAL PROPERTIES

| | R.O.M. | Stoker |
|-------------------|--------|--------|
| Ash fraction ~ | .065 | .065 |
| Sulfur fraction ~ | .008 | .008 |
| HHV (Btu/lb) ~ | 12800. | 12800. |

FUEL PRICES
 R.O.M. coal (\$/MBtu) ~ 1.88
 Stoker coal (\$/MBtu) ~ 1.99
 Coal/H₂O mix (\$/MBtu) ~ 3.00
 Coal/oil mix (\$/MBtu) ~ 3.50

OPTIONS
 Soot blower multiplier ~ 1.0
 Tube bank mod multiplier ~ 1.0
 Bottom ash pit multiplier ~ 1.0
 SO₂ control multiplier ~ 1.0

LIMESTONE/LIME
 Inert fraction ~ .05

ECONOMIC PARAMETERS
 Inflation & discounting base year ~ 1988
 Gen infla index (1987 to base yr) ~ 1.040
 Gas infla index (1988 to base yr) ~ 1.000
 Oil infla index (1988 to base yr) ~ 1.000
 Coal infla index (1988 to base yr) ~ 1.000
 Project start year ~ 1990
 Project life (yr) ~ 30
 Depreciation life (yr) ~ 15
 General inflation rate (I/yr) ~ 0
 Type of gas escalation ~ egas
 Type of oil escalation ~ eoil
 Type of coal escalation ~ ecoal
 Discount rate (I/yr) ~ 10
 Rate of return on invest (I/yr) ~ 17
 Amount of working capital (month) ~ 2
 Federal income tax rate (I) ~ 34
 Local prop tax (& insur) rate (I) ~ 2

Primary fuel is 3
NATURAL GAS
 1-#6 Oil, 2-#2 Oil, 3-MG

| | | REAL ESCALATION RATE (I/yr) | | | |
|------|----------------------------|-----------------------------|-------|-------|--------------------|
| FUEL | TYPE OF FUEL ESCALATION | 1988 | 1990 | 1995 | 2000 AND BEYOND |
| | | -1979 | -1995 | -2000 | |
| Gas | egas | 2.28 | 4.70 | 5.49 | 2.75 |
| Oil | eoil | .17 | 4.16 | 5.55 | 2.77 |
| Coal | ecoal | 1.46 | 1.76 | 1.61 | .81 |

1:17 PM Oct 21, 1988

TIMBER AFB: 2 X 75 MBtu/hr. FUEL REAL ESCALATION = AEO 1987

Total steam output = 150.0 MBtu/hr

Cost base year = 1986

Boiler capacity factor = .712

Primary fuel = NATURAL GAS

Number of units for refit = 2

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL \$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|------------------|--------------|----------------|----------------|
| | | | | | FUEL \$ | MAINT O & M \$ | OTHER O & M \$ |
| Natural gas boiler | -- | .800 | 2.85 | .0 | 3333.0 | 302.7 | 672.7 |
| #2 Oil fired boiler | -- | .800 | 4.71 | .0 | 5508.2 | 302.7 | 672.7 |
| #6 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| Micronized coal refit | 2 | .800 | 1.68 | 8643.9 | 1864.7 | 557.2 | 1180.1 |
| Slagging burner refit | 2 | .800 | 1.68 | 11066.9 | 1864.7 | 557.2 | 1180.1 |
| Modular FBC refit | 2 | .780 | 1.68 | 12597.3 | 1489.6 | 520.4 | 1112.6 |
| Stoker firing refit | 2 | .740 | 1.89 | 10205.7 | 2515.9 | 817.5 | 1143.0 |
| Coal/water slurry | 2 | .750 | 3.00 | 8783.5 | 3742.3 | 520.4 | 1007.8 |
| Coal/oil slurry | 2 | .780 | 3.50 | 5667.4 | 4198.1 | 414.4 | 887.7 |
| Low Btu gasifier refit | 3 | .658 | 1.89 | 13413.2 | 2826.9 | 480.0 | 2018.5 |
| Packaged shell stoker | 3 | .740 | 1.69 | 13237.9 | 2515.9 | 817.5 | 1215.0 |
| Packaged shell FBC | 3 | .780 | 1.68 | 12571.5 | 2068.1 | 520.4 | 1180.1 |
| Field erected stoker | 1 | .780 | 1.89 | 15787.4 | 2306.9 | 814.4 | 1006.9 |
| Field erected FBC | 1 | .800 | 1.68 | 14323.9 | 1864.7 | 604.4 | 1001.8 |
| Pulverized coal boiler | 1 | .800 | 1.68 | 17958.5 | 1864.7 | 907.9 | 1076.6 |
| Circulating FBC | 1 | .810 | 1.68 | 17761.7 | 1840.4 | 517.3 | 1074.5 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|--|------------------|---|---------------------|------------------------------------|---|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT \$ | BENEFIT/ COST RATIO | PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT \$ | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 49,607 | 1.000 | <--- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 72,667 | -- | | | |
| #6 Oil fired boiler | -- | -- | 0 | -- | | | |
| Micronized coal refit | Not applicable because of space limitations | | | | | | |
| Slagging burner refit | Not applicable because of space limitations | | | | | | |
| Modular FBC refit | Not applicable because of space limitations | | | | | | |
| Stoker firing refit | Not applicable because existing boilers were designed for #2 oil | | | | | | |
| Coal/water slurry | 2 | 48,728 | 52,487 | .845 | >31 | 57,280 | .866 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | Not applicable because of space limitations | | | | | | |
| Packaged shell stoker | 3 | 49,386 | 50,821 | .976 | >31 | 58,703 | .845 |
| Packaged shell FBC | 3 | 48,086 | 43,308 | 1.145 | 16.3 | 50,653 | .979 |
| Field erected stoker | 1 | 46,853 | 50,094 | .990 | >31 | 59,196 | .838 |
| Field erected FBC | 1 | 45,682 | 43,090 | 1.151 | 16.5 | 51,281 | .967 |
| Pulverized coal boiler | 1 | 45,682 | 49,390 | 1.004 | 30.2 | 59,528 | .833 |
| Circulating FBC | 1 | 45,118 | 45,496 | 1.090 | 20.7 | 55,428 | .895 |

TINIAN AFM: 2 X 75 Mbtu/hr. FUEL REAL ESCALATION = ZERO

Total steam output = 150.0 Mbtu/hr
 Boiler capacity factor = .712
 Number of units for refit = 2
 Hydrated lime price (\$/ton) = 40.00
 Ash disposal price (\$/ton) = 10.00
 Electric price (cents/kWh) = 4.80
 Labor rate (\$/yr) = 35.00
 Limestone price (\$/ton) = 20.00

FUEL PRICES
 Natural gas price (\$/Mbtu) = 2.85
 #2 Oil price (\$/Mbtu) = 4.74
 #6 Oil price (\$/Mbtu) = .00

COAL PROPERTIES
 R.O.M. Stoker
 Ash fraction = .065 .065
 Sulfur fraction = .008 .008
 HHV (Btu/lb) = 12800. 12800.

FUEL PRICES
 R.O.M. coal (\$/Mbtu) = 1.68
 Stoker coal (\$/Mbtu) = 1.99
 Coal/H₂O mix (\$/Mbtu) = 3.00
 Coal/oil mix (\$/Mbtu) = 3.50

OPTIONS
 Soot blower multiplier = 1.0
 Tube bank mod multiplier = 1.0
 Bottom ash pit multiplier = 1.0
 SO2 control multiplier = 1.0

LIMESTONE/LIME
 Inert fraction = .05

Primary fuel is 3
 NATURAL GAS
 1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988
 Gen infla index (1987 to base yr) = 1.040
 Gas infla index (1988 to base yr) = 1.000
 Oil infla index (1988 to base yr) = 1.000
 Coal infla index (1988 to base yr) = 1.000
 Project start year = 1990
 Project life (yr) = 30
 Depreciation life (yr) = 15
 General inflation rate (I/yr) = 0
 Type of gas escalation = zero
 Type of oil escalation = zero
 Type of coal escalation = zero
 Discount rate (I/yr) = 10
 Rate of return on invest (I/yr) = 17
 Amount of working capital (month) = 2
 Federal income tax rate (I) = 34
 Local prop tax (& insur) rate (I) = 2

| FUEL | TYPE OF FUEL ESCALATION | REAL ESCALATION RATE (I/yr) | | | |
|------|----------------------------|-----------------------------|---------------|---------------|--------------------|
| | | 1988 -1990 | 1990 -1995 | 1995 -2000 | 2000 AND BEYOND |
| Gas | zero | 0 | 0 | 0 | 0 |
| Oil | zero | 0 | 0 | 0 | 0 |
| Coal | zero | 0 | 0 | 0 | 0 |

1:22 PM Oct 21, 1988

YIMKE AFB: 2 X 75 MBtu/hr. FUEL REAL ESCALATION = ZERO

Total steam output = 150.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .712

Primary fuel = NATURAL GAS

Number of units for refit = 2

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & H k\$ | OTHER O & H k\$ |
| Natural gas boiler | -- | .800 | 2.85 | .0 | 3333.0 | 302.7 | 672.7 |
| #2 Oil fired boiler | -- | .800 | 4.71 | .0 | 3508.2 | 302.7 | 672.7 |
| #6 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| Micronized coal refit | 2 | .800 | 1.68 | 6843.0 | 1054.7 | 557.2 | 1180.1 |
| Slagging burner refit | 2 | .800 | 1.68 | 11066.0 | 1064.7 | 557.2 | 1180.1 |
| Modular FBC refit | 2 | .780 | 1.68 | 12597.3 | 1980.8 | 520.4 | 1112.8 |
| Stoker firing refit | 2 | .740 | 1.99 | 10292.7 | 2515.9 | 817.5 | 1143.0 |
| Coal/water slurry | 2 | .750 | 3.00 | 8793.5 | 3742.3 | 520.4 | 1007.8 |
| Coal/oil slurry | 2 | .780 | 3.50 | 5567.4 | 4108.1 | 414.4 | 887.7 |
| Low Btu gasifier refit | 3 | .659 | 1.99 | 13413.2 | 2826.9 | 480.0 | 2019.5 |
| Packaged shell stoker | 3 | .740 | 1.99 | 13237.9 | 2515.9 | 817.5 | 1215.0 |
| Packaged shell FBC | 3 | .780 | 1.68 | 12571.5 | 2068.1 | 520.4 | 1190.1 |
| Field erected stoker | 1 | .780 | 1.99 | 13787.4 | 2386.9 | 814.4 | 1006.9 |
| Field erected FBC | 1 | .800 | 1.68 | 14323.9 | 1064.7 | 604.4 | 1001.8 |
| Pulverized coal boiler | 1 | .800 | 1.68 | 17958.5 | 1064.7 | 907.9 | 1076.6 |
| Circulating FBC | 1 | .810 | 1.68 | 17761.7 | 1040.4 | 517.3 | 1074.5 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|--|------------------|--|---------------------|--------------------|--|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO | PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 33,914 | 1.000 | <--- | Existing system, primary fuel | |
| #2 Oil fired boiler | -- | -- | 50,861 | -- | | | |
| #6 Oil fired boiler | -- | -- | 0 | -- | | | |
| Micronized coal refit | Not applicable because of space limitations | | | | | | |
| Slagging burner refit | Not applicable because of space limitations | | | | | | |
| Modular FBC refit | Not applicable because of space limitations | | | | | | |
| Stoker firing refit | Not applicable because existing boilers were designed for #2 oil | | | | | | |
| Coal/water slurry | 2 | 48,728 | 47,275 | .717 | >31 | 51,020 | .653 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | Not applicable because of space limitations | | | | | | |
| Packaged shell stoker | 3 | 49,386 | 47,317 | .717 | >31 | 55,100 | .616 |
| Packaged shell FBC | 3 | 49,086 | 40,428 | .839 | >31 | 47,690 | .711 |
| Field erected stoker | 1 | 46,853 | 46,770 | .725 | >31 | 55,777 | .608 |
| Field erected FBC | 1 | 45,682 | 40,354 | .840 | >31 | 48,467 | .760 |
| Pulverized coal boiler | 1 | 45,682 | 46,653 | .727 | >31 | 56,714 | .598 |
| Circulating FBC | 1 | 45,118 | 42,793 | .793 | >31 | 52,649 | .644 |

1:22 PM Oct 21, 1988

ARNOLD AFB: AFSC

1. BACKGROUND

Arnold AFB is located near Manchester, Tennessee. The main steam plant consists of 3 x 72-MBtu/h and a 24-MBtu/h boiler, all of which were designed for medium volatile bituminous coal but now fire natural gas and distillate (No. 2) oil (secondary fuel). Coal-firing was replaced by gas and oil in 1970.

All units are Edgemoor Iron Works waterwall sterling-type boilers with air preheaters manufactured by Edgemoor installed on the three larger units. Saturated steam at 200 psig is produced. According to C. H. Guernsey and Co., the large boilers have efficiencies of 76%, and the small boiler's efficiency is 71%. Peak load is reported to be 210 MBtu/h, and the yearly fuel use ranges from 600,000 to 700,000 MBtu/year (an average of 69-80 MBtu/h).

2. HEATING PLANT UNITS

Heating Plant No. 1411:

24 MBtu/h, 3 x 72 MBtu/h, Edgemoor Iron Works, 1951

3. IDEAL CAPACITY FACTOR ANALYSIS

The maximum possible capacity factors as a function of project size are given below for plant No. 1411.

| Fuel input (MBtu/h) | FY 1986 ideal capacity factor |
|---------------------------|--|
| 60 | 0.99 |
| 70 | 0.94 |
| 80 | 0.89 |
| 90 | 0.83 |
| 100 | 0.77 |
| 110 | 0.72 |
| 120 | 0.66 |

4. ENERGY PRICES

FY 1986 Price Data:

Electricity = \$13.0/MBtu = 4.44¢/kWh
 Distillate = \$6.88/MBtu
 Natural gas = \$3.81/MBtu

C. H. Guernsey and Co. Survey:

Electricity = 4.5¢/kWh

Natural gas = \$3.97/MBtu

5. COAL PROPERTIES AND PRICES

| | Stoker | ROM |
|-------------------------------------|-------------|------------|
| Origin | Harlan, Ky. | Sarah, Ky. |
| HHV, Btu/lb | 13,200 | 12,000 |
| % Ash | 6-8 | 10 |
| % Sulfur | 1.3 | 1.5 |
| % Nitrogen | | |
| Ash-softening temperature, °F | 2600 | 2600 |
| Swelling index | 4-6 | 3.5-4 |
| Top size, in. | 1 1/4 | 2 |
| Bottom size, in. | 1/4 | 0 |
| Fines, % | 5 | 35 |
| Grindability index | 46 | 47 |
| Cost at mine, \$/ton | 33 | 23 |
| Delivered cost, \$/ton | 52 | 42 |
| Energy cost, \$/10 ⁶ Btu | 1.97 | 1.75 |

6. ENVIRONMENTAL REGULATIONS

6.1 Air Pollution Emission Limits for New Sources

SO₂. No emission limits for boilers <100 MBtu/h; for boilers >100 MBtu/h: FBC - 90% reduction to meet limit of 1.2 lb/MBtu; emerging technology - 50% reduction to meet limit of 0.6 lb/MBtu.

NO_x. No emission limits for boilers <100 MBtu/h; for boilers >100 MBtu/h: spreader stoker and FBC - 0.6 lb/MBtu; pulverized coal - 0.7 lb/MBtu.

Particulates. For boilers <100 MBtu/h: $E = 0.6[10/(MBtu/h)]^{0.5566}$; for 72 MBtu/h: 0.2 lb/MBtu; for boilers >100 MBtu/h: 0.05 lb/MBtu.

6.2 Coal-Pile Runoff

Limit: Total suspended solids - 50 mg/L.

6.3 Ash Disposal

Coal ash is classified as solid waste extraction procedure (EP) will be required to determine if the waste is nonhazardous. If the test is negative, the ash will be classified as special waste. The Nashville Field Office will issue a "Special Waste Approval," necessary to dispose of the ash in an existing landfill.

7. OTHER CONSIDERATIONS

None

8. COAL-CONVERSION PROJECT OUTLOOK

It appears to be most economical to convert one 72-MBtu/h unit back to coal. This corresponds to a fuel input of about 95 MBtu/h. The maximum possible capacity factor based on monthly FY 1986 data is about 80%. With a 90% equipment availability, a realistic capacity factor would be about 72%.

8.1 Effect of Environmental Regulations on Selection of Combustion Technologies

SO₂ and NO_x. Any of the combustion technologies being considered could be employed without requiring any measures for NO_x or SO₂ reduction because the proposed conversion project is smaller than 100 MBtu/h.

Particulates. Bag filters or electrostatic precipitators would be required to comply with the particulate emission limits.

8.2 Physical Space and Aesthetics

Heating Plant. The existing boiler plant was originally designed for coal. There is space available for reinstalling combustion equipment at the existing boiler or for construction of a new boiler at another site on base.

Coal-Handling Equipment. There is space available for installing coal-handling equipment at the existing boilers.

Coal Pile. There is space available for a coal pile at the existing boiler plant or at a new site on base.

8.3 Technical Risk of Combustion Technologies

These boilers were originally designed for pulverized coal-firing. The least technical risk would be for conversion to micronized coal-firing, because no SO₂ reduction measures will be required for one boiler because it is <100 MBtu/h.

9. COGENERATION PROJECT OUTLOOK

Cogeneration would probably not be economical at this base because of the reasonably low electric power rates that are available from TVA.

10. INPUT AND LCC SUMMARY SPREADSHEETS

ARNOLD AFS: 1 X 72 Mbtu/hr. ECONOMIC PARAMETERS - NOMINAL VALUES

Total steam output = 72.0 Mbtu/hr
 Boiler capacity factor = .720
 Number of units for refit = 1
 Hydrated lime price (\$/ton) = 40.00
 Ash disposal price (\$/ton) = 10.00
 Electric price (cents/kWh) = 4.50
 Labor rate (\$/yr) = 35.00
 Limestone price (\$/ton) = 20.00

FUEL PRICES
 Natural gas price (\$/Mbtu) = 3.97
 #2 Oil price (\$/Mbtu) = 4.71
 #6 Oil price (\$/Mbtu) = .00

OPTIONS
 Soot blower multiplier = .0
 Tube bank mod multiplier = .0
 Bottom ash pit multiplier = 1.0
 SO2 control multiplier = .0

LIMESTONE/LIME
 Inert fraction = .05

COAL PROPERTIES
 R.O.M. Stoker
 Ash fraction = .100 .070
 Sulfur fraction = .015 .013
 HHV (Btu/lb) = 12000. 13200.

FUEL PRICES
 R.O.M. coal (\$/Mbtu) = 1.75
 Stoker coal (\$/Mbtu) = 1.97
 Coal/H2O mix (\$/Mbtu) = 3.00
 Coal/oil mix (\$/Mbtu) = 3.50

Primary fuel is 3
NATURAL GAS
 1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1985
 Gen infla index (1987 to base yr) = 1.040
 Gas infla index (1988 to base yr) = 1.000
 Oil infla index (1988 to base yr) = 1.000
 Coal infla index (1988 to base yr) = 1.000
 Project start year = 1990
 Project life (yr) = 30
 Depreciation life (yr) = 15
 General inflation rate (I/yr) = 0
 Type of gas escalation = egas
 Type of oil escalation = eoil
 Type of coal escalation = ecoal
 Discount rate (I/yr) = 10
 Rate of return on invest (I/yr) = 17
 Amount of working capital (month) = 2
 Federal income tax rate (I) = 34
 Local prop tax (& insur) rate (I) = 2

| FUEL | TYPE OF FUEL ESCALATION | REAL ESCALATION RATE (I/yr) | | | |
|------|----------------------------|-----------------------------|---------------|---------------|--------------------|
| | | 1988 -1990 | 1990 -1995 | 1995 -2000 | 2000 AND BEYOND |
| Gas | egas | 3.89 | 8.87 | 5.77 | 5.77 |
| Oil | eoil | 4.86 | 7.87 | 4.16 | 4.16 |
| Coal | ecoal | 1.16 | 2.31 | 1.19 | 1.19 |

10:52 AM Oct 19, 1988

ARNOLD AFS: 1 X 72 Mbtu/hr. ECONOMIC PARAMETERS - NOMINAL VALUES

Total steam output = 72.0 Mbtu/hr

Cost base year = 1988

Boiler capacity factor = .720

Primary fuel = NATURAL GAS

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/Mbtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | OTHER O & M k\$ |
| Natural gas boiler | -- | .800 | 3.97 | .0 | 2253.6 | 202.2 | 525.0 |
| #2 Oil fired boiler | -- | .800 | 4.71 | .0 | 2673.6 | 202.2 | 525.0 |
| #6 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| Micronized coal refit | 1 | .800 | 1.75 | 3139.6 | 993.4 | 420.3 | 719.5 |
| Slagging burner refit | 1 | .800 | 1.75 | 5474.2 | 993.4 | 420.3 | 719.5 |
| Modular FBC refit | 1 | .790 | 1.75 | 6299.9 | 1006.0 | 399.6 | 695.9 |
| Stoker firing refit | 1 | .780 | 1.97 | 3653.3 | 1177.1 | 399.6 | 675.2 |
| Coal/water slurry | 1 | .750 | 3.60 | 2842.2 | 1816.5 | 399.6 | 607.3 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2536.6 | 2037.7 | 318.2 | 573.0 |
| Low Btu gasifier refit | 2 | .679 | 1.97 | 6343.5 | 1319.3 | 368.5 | 944.7 |
| Packaged shell stoker | 2 | .760 | 1.97 | 5475.5 | 1177.1 | 399.6 | 770.8 |
| Packaged shell FBC | 2 | .760 | 1.75 | 8908.8 | 1045.7 | 399.6 | 792.5 |
| Field erected stoker | 1 | .800 | 1.97 | 8119.7 | 1118.5 | 397.2 | 664.6 |
| Field erected FBC | 1 | .800 | 1.75 | 8950.4 | 993.4 | 464.1 | 695.6 |
| Pulverized coal boiler | 1 | .820 | 1.75 | 9468.3 | 969.2 | 468.9 | 724.4 |
| Circulating FBC | 1 | .810 | 1.75 | 10790.0 | 981.1 | 397.2 | 762.9 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|---|------------------|--|---------------------|------------------------------------|--|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO | DISCOUNTED PAYBACK PERIOD, YR | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 45,488 | 1.000 | <--- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 46,608 | -- | | | |
| #6 Oil fired boiler | -- | -- | 0 | -- | | | |
| Micronized coal refit | 1 | 23,652 | 21,239 | 2.141 | 3.9 | 23,368 | 1.946 |
| Slagging burner refit | 1 | 23,652 | 23,168 | 1.983 | 5.7 | 26,489 | 1.717 |
| Modular FBC refit | 1 | 23,951 | 23,600 | 1.927 | 6.2 | 27,334 | 1.663 |
| Stoker firing refit | Not applicable because existing boiler was designed for pulverized coal | | | | | | |
| Coal/water slurry | 1 | 25,229 | 27,624 | 1.646 | 5.8 | 29,789 | 1.526 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | 2 | 25,348 | 28,215 | 1.612 | 8.3 | 32,101 | 1.416 |
| Packaged shell stoker | 2 | 22,633 | 25,101 | 1.811 | 6.4 | 28,476 | 1.597 |
| Packaged shell FBC | 2 | 24,897 | 25,226 | 1.802 | 7.1 | 29,303 | 1.552 |
| Field erected stoker | 1 | 21,502 | 25,887 | 1.756 | 7.9 | 30,572 | 1.487 |
| Field erected FBC | 1 | 23,652 | 26,247 | 1.732 | 8.4 | 31,346 | 1.451 |
| Pulverized coal boiler | 1 | 23,075 | 26,716 | 1.702 | 8.9 | 32,080 | 1.417 |
| Circulating FBC | 1 | 23,360 | 27,578 | 1.648 | 9.7 | 33,610 | 1.353 |

10:52 AM Oct 19, 1988

ARNOLD AFS: 1 X 72 Mbtu/hr. FUEL REAL ESCALATION - APO 1987

Total steam output = 72.0 Mbtu/hr

Boiler capacity factor = .720

Number of units for refit = 1

Hydrated lime price (\$/ton) = 40.00

Ash disposal price (\$/ton) = 10.00

Electric price (cents/kWh) = 4.50

Labor rate (k\$/yr) = 35.00

Limestone price (\$/ton) = 20.00

FUEL PRICES

Natural gas price (\$/Mbtu) = 3.97

#2 Oil price (\$/Mbtu) = 4.71

#6 Oil price (\$/Mbtu) = .00

OPTIONS

Soot blower multiplier = .0

Tube bank mod multiplier = .0

Bottom ash pit multiplier = 1.0

SO2 control multiplier = .0

LIMESTONE/LIME

Inert fraction = .05

COAL PROPERTIESR.O.M. Stoker

Ash fraction = .100 .670

Sulfur fraction = .015 .013

HHV (Btu/lb) = 12000. 13200.

FUEL PRICES

R.O.M. coal (\$/Mbtu) = 1.75

Stoker coal (\$/Mbtu) = 1.97

Coal/H2O mix (\$/Mbtu) = 3.00

Coal/oil mix (\$/Mbtu) = 3.50

Primary fuel is 3

NATURAL GAS

1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988

Gen infla index (1987 to base yr) = 1.040

Gas infla index (1988 to base yr) = 1.000

Oil infla index (1988 to base yr) = 1.000

Coal infla index (1988 to base yr) = 1.000

Project start year = 1990

Project life (yr) = 30

Depreciation life (yr) = 15

General inflation rate (I/yr) = 0

Type of gas escalation = egas

Type of oil escalation = eoil

Type of coal escalation = ecoal

Discount rate (I/yr) = 10

Rate of return on invest (I/yr) = 17

Amount of working capital (month) = 2

Federal income tax rate (%) = 34

Local prop tax (& insur) rate (%) = 2

REAL ESCALATION RATE (I/yr)

| FUEL | TYPE OF FUEL ESCALATION | 1988 | 1990 | 1995 | 2000 AND BEYOND |
|------|----------------------------|-------|-------|-------|--------------------|
| | | -1990 | -1995 | -2000 | |
| Gas | egas | 2.28 | 4.70 | 5.49 | 2.75 |
| Oil | eoil | .17 | 4.16 | 5.55 | 2.77 |
| Coal | ecoal | 1.46 | 1.76 | 1.61 | .81 |

11:00 AM Oct 19, 1988

ARNOLD AFS: 1 X 72 MBtu/hr. FUEL REAL ESCALATION = AEO 1987

Total steam output = 72.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .720

Primary fuel = NATURAL GAS

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL, EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | OTHER O & M k\$ |
| | | | | | | | |
| Natural gas boiler | -- | .800 | 3.97 | .0 | 2253.6 | 202.2 | 525.0 |
| #2 Oil fired boiler | -- | .800 | 4.71 | .0 | 2673.6 | 202.2 | 525.0 |
| #6 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| Micronized coal refit | 1 | .800 | 1.75 | 3139.6 | 993.4 | 420.3 | 719.5 |
| Slagging burner refit | 1 | .800 | 1.75 | 5474.2 | 993.4 | 420.3 | 719.5 |
| Modular FBC refit | 1 | .790 | 1.75 | 6299.9 | 1006.0 | 399.6 | 695.9 |
| Stoker firing refit | 1 | .760 | 1.97 | 3653.3 | 1177.1 | 399.6 | 675.2 |
| Coal/water slurry | 1 | .750 | 3.00 | 2842.2 | 1816.5 | 399.6 | 607.3 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2536.6 | 2037.7 | 318.2 | 573.0 |
| Low Btu gasifier refit | 2 | .679 | 1.97 | 6343.5 | 1318.3 | 368.5 | 944.7 |
| Packaged shell stoker | 2 | .760 | 1.97 | 5475.5 | 1177.1 | 399.6 | 770.8 |
| Packaged shell FBC | 2 | .760 | 1.75 | 6908.8 | 1045.7 | 399.6 | 792.5 |
| Field erected stoker | 1 | .800 | 1.97 | 8119.7 | 1118.3 | 397.2 | 664.6 |
| Field erected FBC | 1 | .800 | 1.75 | 8950.4 | 993.4 | 464.1 | 695.6 |
| Pulverized coal boiler | 1 | .820 | 1.75 | 9468.3 | 969.2 | 468.9 | 724.4 |
| Circulating FBC | 1 | .810 | 1.75 | 10790.0 | 981.1 | 397.2 | 762.9 |

| AIR FORCE PROJECT | | | | | | PRIVATE PROJECT | |
|------------------------|---|----------------|------------------------|------------------|------------------------------------|------------------------|------------------|
| | | | LIFE CYCLE COST, | DISCOUNTED | | LIFE CYCLE COST, | |
| | # OF | COAL | DISCOUNTED | BENEFIT/ COST | PAYBACK | DISCOUNTED | BENEFIT/ COST |
| TECHNOLOGY | UNITS | USE, ton/yr | AS SPENT k\$ | RATIO | PERIOD, yr | AS SPENT k\$ | RATIO |
| Natural gas boiler | -- | -- | 34,065 | 1.000 | <--- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 37,312 | -- | | | |
| #6 Oil fired boiler | -- | -- | 0 | -- | | | |
| Micronized coal refit | 1 | 23,652 | 21,081 | 1.616 | 4.7 | 23,206 | 1.468 |
| Slagging burner refit | 1 | 23,652 | 23,010 | 1.480 | 7.3 | 26,326 | 1.204 |
| Modular FBC refit | 1 | 23,951 | 23,440 | 1.453 | 8.0 | 27,169 | 1.254 |
| Stoker firing refit | Not applicable because existing boiler was designed for pulverized coal | | | | | | |
| Coal/water slurry | 1 | 25,229 | 27,335 | 1.246 | 9.0 | 29,492 | 1.155 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | 2 | 25,348 | 28,005 | 1.216 | 12.4 | 31,885 | 1.068 |
| Packaged shell stoker | 2 | 22,633 | 24,914 | 1.367 | 8.6 | 28,284 | 1.204 |
| Packaged shell FBC | 2 | 24,897 | 25,060 | 1.359 | 9.6 | 29,132 | 1.169 |
| Field erected stoker | 1 | 21,502 | 25,709 | 1.325 | 10.7 | 30,389 | 1.121 |
| Field erected FBC | 1 | 23,652 | 26,089 | 1.306 | 11.5 | 31,183 | 1.092 |
| Pulverized coal boiler | 1 | 23,075 | 26,562 | 1.282 | 12.2 | 31,922 | 1.067 |
| Circulating FBC | 1 | 23,360 | 27,422 | 1.242 | 13.6 | 33,450 | 1.018 |

11:00 AM Oct 19, 1988

ARNOLD AFS: 1 X 72 MBtu/hr. FUEL REAL ESCALATION = ZERO

Total steam output = 72.0 MBtu/hr

Boiler capacity factor = .720

Number of units for refit = 1

Hydrated lime price (\$/ton) = 40.00

Ash disposal price (\$/ton) = 10.00

Electric price (cents/kWh) = 4.50

Labor rate (\$/yr) = 35.00

Limestone price (\$/ton) = 20.00

FUEL PRICES

Natural gas price (\$/MBtu) = 3.97

#2 Oil price (\$/MBtu) = 4.71

#6 Oil price (\$/MBtu) = .00

OPTIONS

Soot blower multiplier = .0

Tube bank mod multiplier = .0

Bottom ash pit multiplier = 1.0

SO2 control multiplier = .0

LIMESTONE/LIME

Inert fraction = .05

COAL PROPERTIESR.O.M. Stoker

Ash fraction = .100 .070

Sulfur fraction = .015 .013

HHV (Btu/lb) = 12000. 13200.

FUEL PRICES

R.O.M. coal (\$/MBtu) = 1.75

Stoker coal (\$/MBtu) = 1.97

Coal/H2O mix (\$/MBtu) = 3.00

Coal/oil mix (\$/MBtu) = 3.50

Primary fuel is 3

NATURAL GAS

1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988

Gen infla index (1987 to base yr) = 1.040

Gas infla index (1988 to base yr) = 1.000

Oil infla index (1988 to base yr) = 1.000

Coal infla index (1988 to base yr) = 1.000

Project start year = 1990

Project life (yr) = 30

Depreciation life (yr) = 15

General inflation rate (I/yr) = 0

Type of gas escalation = zero

Type of oil escalation = zero

Type of coal escalation = zero

Discount rate (I/yr) = 10

Rate of return on invest (I/yr) = 17

Amount of working capital (month) = 2

Federal income tax rate (I) = 34

Local prop tax (& insur) rate (I) = 2

| FUEL | TYPE OF FUEL ESCALATION | REAL ESCALATION RATE (I/yr) | | | |
|------|----------------------------|-----------------------------|---------------|---------------|--------------------|
| | | 1988 -1990 | 1990 -1995 | 1995 -2000 | 2000 AND BEYOND |
| Gas | zero | 0 | 0 | 0 | 0 |
| Oil | zero | 0 | 0 | 0 | 0 |
| Coal | zero | 0 | 0 | 0 | 0 |

11:06 AM Oct 19, 1988

ARNOLD AYS: 1 X 72 MBtu/hr. FUEL REAL ESCALATION = ZERO

Total steam output = 72.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .720

Primary fuel = NATURAL GAS

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | OTHER O & M k\$ |
| Natural gas boiler | -- | .800 | 3.97 | .0 | 2253.6 | 202.2 | 525.0 |
| #2 Oil fired boiler | -- | .800 | 4.71 | .0 | 2673.6 | 202.2 | 525.0 |
| #6 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| Micronized coal refit | 1 | .800 | 1.75 | 3138.6 | 993.4 | 420.3 | 719.5 |
| Slagging burner refit | 1 | .800 | 1.75 | 5474.2 | 993.4 | 420.3 | 719.5 |
| Modular FBC refit | 1 | .790 | 1.75 | 6299.9 | 1006.0 | 398.6 | 695.9 |
| Stoker firing refit | 1 | .760 | 1.97 | 3653.3 | 1177.1 | 399.6 | 675.2 |
| Coal/water slurry | 1 | .750 | 3.00 | 2642.2 | 1816.5 | 399.6 | 607.3 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2538.6 | 2037.7 | 318.2 | 573.0 |
| Low Btu gasifier refit | 2 | .679 | 1.97 | 5343.5 | 1318.3 | 368.5 | 944.7 |
| Packaged shell stoker | 2 | .760 | 1.97 | 5475.5 | 1177.1 | 399.6 | 770.8 |
| Packaged shell FBC | 2 | .760 | 1.75 | 6908.8 | 1045.7 | 399.6 | 792.5 |
| Field erected stoker | 1 | .800 | 1.97 | 8119.7 | 1116.3 | 397.2 | 664.8 |
| Field erected FBC | 1 | .800 | 1.75 | 8950.4 | 993.4 | 464.1 | 695.6 |
| Pulverized coal boiler | 1 | .820 | 1.75 | 9468.3 | 969.2 | 468.9 | 724.4 |
| Circulating FBC | 1 | .810 | 1.75 | 10790.0 | 981.1 | 397.2 | 762.9 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|---|------------------|--|--------------------|------------------------------------|--|--------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/COST RATIO | PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/COST RATIO |
| Natural gas boiler | -- | -- | 23,455 | 1.000 | <--- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 26,728 | -- | | | |
| #6 Oil fired boiler | -- | -- | 0 | -- | | | |
| Micronized coal refit | 2 | 23,652 | 19,697 | 1.191 | 6.4 | 21,783 | 1.077 |
| Slagging burner refit | 1 | 23,652 | 21,627 | 1.085 | 12.8 | 24,903 | .942 |
| Modular FBC refit | 1 | 23,951 | 22,038 | 1.064 | 15.2 | 25,729 | .912 |
| Stoker firing refit | Not applicable because existing boiler was designed for pulverized coal | | | | | | |
| Coal/water slurry | 1 | 25,229 | 24,805 | .946 | >31 | 26,891 | .872 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | 2 | 25,346 | 26,169 | .896 | >31 | 29,997 | .762 |
| Packaged shell stoker | 2 | 22,633 | 23,274 | 1.008 | 25.2 | 26,598 | .882 |
| Packaged shell FBC | 2 | 24,897 | 23,653 | .994 | >31 | 27,634 | .849 |
| Field erected stoker | 1 | 21,502 | 24,152 | .971 | >31 | 28,787 | .815 |
| Field erected FBC | 1 | 23,652 | 24,795 | .949 | >31 | 29,761 | .788 |
| Pulverized coal boiler | 1 | 23,075 | 25,212 | .930 | >31 | 30,534 | .768 |
| Circulating FBC | 1 | 23,360 | 26,056 | .900 | >31 | 32,045 | .732 |

HANSCOM AFB: AFSC

1. BACKGROUND

Hanscom AFB is located near Boston, in Bedford, Massachusetts. There is a central heating plant with four boilers, each with a capacity near 50 MBtu/h. All boilers were designed for residual (No. 6) oil combustion and are two-drum sterling water-tube boilers. The primary fuel is No. 6 oil, with natural gas as the secondary fuel. The steam plant produces 100 psig saturated steam. The yearly average fuel use is roughly 85 MBtu/h.

2. HEATING PLANT UNITS

Heating Plant No. 1201:

3 x 51.3 MBtu/h, Eric City Iron Works, 1953
1 x 49.4 MBtu/h, E. Keeler Co., 1961

3. IDEAL CAPACITY FACTOR ANALYSIS

The ideal capacity factors listed below were calculated from monthly fuel-use data for plant No. 1201.

| Fuel input (MBtu/h) | FY 1986 ideal capacity factor |
|---------------------------|--|
| 60 | 0.99 |
| 70 | 0.94 |
| 80 | 0.90 |
| 90 | 0.84 |
| 100 | 0.80 |
| 120 | 0.70 |
| 150 | 0.56 |

4. ENERGY PRICES

FY 1986 Price Data:

Electricity = 6.8¢/kWh
Natural gas = varied from \$2.4 to \$3.9/MBtu
Residual oil = \$5.13/MBtu

C. H. Guernsey and Co. Survey:

Electricity = 6.07¢/kWh
Natural gas = \$6.2/MBtu (looks like an error)
Residual oil = \$4.67/MBtu

5. COAL PROPERTIES AND PRICES

| | Stoker | ROM |
|-------------------------------------|------------|------------|
| Origin | Slago, Pa. | Slago, Pa. |
| HHV, Btu/lb | 13,000 | 12,800 |
| % Ash | 7-9 | 8-10 |
| % Sulfur | 1.8-2.2 | 1.8-2.2 |
| % Nitrogen | 1.32 | 1.30 |
| Ash-softening temperature, °F | 2500 | 2300 |
| Swelling index | 6-8 | 6-8 |
| Top size, in. | 1 5/8 | 2 |
| Bottom size, in. | 1/2 | 0 |
| Fines, % | 5 | |
| Grindability index | 50-55 | 50-55 |
| Cost at mine, \$/ton | 40 | 26.50 |
| Delivered cost, \$/ton | 66.00 | 52.50 |
| Energy cost, \$/10 ⁶ Btu | 2.54 | 2.05 |

6. ENVIRONMENTAL REGULATIONS

6.1 Air Pollution Emission Limits for New Sources

SO₂. 0.55 lb/MBtu.

No_x. No emission limits for boilers <100 MBtu/h; for boilers >100 MBtu/h: spreader stoker and FBC - 0.6 lb/MBtu; pulverized coal - 0.7 lb/MBtu.

Particulates. For boilers >3 and <100 MBtu/h: 0.1 lb/MBtu; for boilers >100 MBtu/h: 0.05 lb/MBtu.

6.2 Coal-Pile Runoff

Limit: Total suspended solids - 50 mg/L.

6.3 Ash Disposal

Ashes are classified as rubbish and may be disposed of in any approved sanitary landfill.

7. OTHER CONSIDERATIONS

In 1980, the planned retirement date for these units was 1985, and the condition of the plant was described as poor. According to the C. H. Guernsey and Co. survey, the same boilers are still in place, but an upgrade of the plant is in progress.

There are discrepancies in the fuel prices and which fuel is used for the boilers. It appears that gas is burned when available, and the cost is \$2.4-3.9/MBtu. From examining the DEIS data, the gas

supply seems to be interruptible and becomes unavailable in the winter months. The price of gas reported in the C. H. Guernsey and Co. survey seems to be an error.

8. COAL-CONVERSION PROJECT OUTLOOK

A likely conversion project would involve conversion or replacement of one unit. If a unit with a coal-firing output capacity of 50 MBtu/h (roughly 62.5 MBtu/h fuel input) were installed, an overall capacity factor of about 88% would be expected (assuming a 90% equipment availability).

8.1 Effect of Environmental Regulations on Selection of Combustion Technologies

SO₂. The strict SO₂ emission limit will require 86% SO₂ reduction while burning 2% sulfur coal, which will necessitate the use of limestone addition with micronized coal or the use of deep-cleaned, coal-water-mixture fuel.

NO_x. Micronized coal or coal-water-mixture firing reportedly can meet the NO_x limit of 0.7 lb/MBtu for pulverized fuel firing.

Particulates. Bag filters or electrostatic precipitators would be required to comply with the particulate emission limits.

8.2 Physical Space and Aesthetics

Heating Plant. The existing boiler plant was designed for No. 6 oil. There is space available for installing coal-water-mixture or micronized coal, but not stoker or FBC, combustion equipment at the existing boiler. There is not enough space available for a new coal-fired boiler at the existing plant, nor is there any site available within a reasonable distance of the heat-distribution system for a new plant.

Coal-Handling Equipment. There is not enough space available for installing coal-handling equipment at the existing boiler. Coal-water mixture fuel could probably be used.

Coal Pile. There is not enough space available for a coal pile on base.

8.3 Technical Risk of Combustion Technologies

Because of space limitations, the only technology available for conversion is coal-water-mixture fuel, and this would be limited to deep-cleaned fuel because of the strict SO₂ limits. The technical risk is moderately high because of the limited experience with this fuel for firing oil-designed boilers at full rated load.

9. COGENERATION PROJECT OUTLOOK

There is not enough space available for locating a new coal-fired cogeneration plant on base within a reasonable distance of the existing heat-distribution system.

10. INPUT AND LCC SUMMARY SPREADSHEETS

NAKSON AVE: 1 X 50 MW/hr. ECONOMIC PARAMETERS - NOMINAL VALUES

Total steam output = 50.0 Mtu/hr
 Boiler capacity factor = .883
 Number of units for refit = 1
 Hydrated lime price (\$/ton) = 40.00
 Ash disposal price (\$/ton) = 10.00
 Electric price (cents/kWh) = 6.10
 Labor rate (\$/hr) = 35.00
 Limestone price (\$/ton) = 20.00

FUEL PRICES
 Natural gas price (\$/Mtu) = 3.50
 #2 Oil price (\$/Mtu) = .00
 #6 Oil price (\$/Mtu) = 3.67

COAL PROPERTIES
 R.O.M. Stoker
 Ash fraction = .090 .080
 Sulfur fraction = .020 .020
 HHV (Btu/lb) = 12800. 13000.

FUEL PRICES
 R.O.M. coal (\$/Mtu) = 2.05
 Stoker coal (\$/Mtu) = 2.54
 Coal/R20 mix (\$/Mtu) = 3.00
 Coal/oil mix (\$/Mtu) = 3.50

OPTIONS
 Soot blower multiplier = .0
 Tube bank mod multiplier = 1.0
 Bottom ash pit multiplier = 1.0
 SO2 control multiplier = 1.0

PRIMARY FUEL
 Primary fuel is 1
 #6 FUEL OIL
 1-#6 Oil, 1-#2 Oil, 3-NG

LIMESTONE/LIME
 Inert fraction = .05

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988
 Gen infla index (1987 to base yr) = 1.040
 Gas infla index (1988 to base yr) = 1.000
 Oil infla index (1988 to base yr) = 1.000
 Coal infla index (1988 to base yr) = 1.000
 Project start year = 1990
 Project life (yr) = 30
 Depreciation life (yr) = 15
 General inflation rate (I/yr) = 0
 Type of gas escalation = egas
 Type of oil escalation = eoil
 Type of coal escalation = ecoal
 Discount rate (I/yr) = 10
 Rate of return on investment (I/yr) = 17
 Amount of working capital (month) = 2
 Federal income tax rate (I) = 34
 Local prop tax (& insur) rate (I) = 2

| | | REAL ESCALATION RATE (I/yr) | | | |
|------|--------------|-----------------------------|-------|-------|----------|
| FUEL | TYPE OF FUEL | 1988 | 1990 | 1995 | 2000 AND |
| | ESCALATION | -1990 | -1995 | -2000 | BEYOND |
| Gas | egas | 3.89 | 8.87 | 5.77 | 5.77 |
| Oil | eoil | 4.86 | 7.87 | 4.16 | 4.16 |
| Coal | ecoal | 1.16 | 2.31 | 1.19 | 1.19 |

4:15 PM Oct 19, 1988

MANSSOM AFB: 1 X 50 MBtu/hr. ECONOMIC PARAMETERS = NOMINAL VALUES

Total steam output = 50.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .883

Primary fuel = #6 FUEL OIL

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL \$K | ANNUAL COSTS | | |
|------------------------|------------|----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL \$K | MAINT O & M \$K | OTHER O & M \$K |
| Natural gas boiler | -- | .800 | 3.50 | .0 | 1682.0 | 165.4 | 494.9 |
| #2 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #6 Oil fired boiler | -- | .800 | 2.67 | .0 | 1774.2 | 165.4 | 494.9 |
| Micronized coal refit | 1 | .800 | 2.05 | 2887.4 | 821.1 | 368.2 | 814.6 |
| Slagging burner refit | 1 | .800 | 2.05 | 4775.9 | 891.1 | 368.2 | 814.6 |
| Modular FBC refit | 1 | .780 | 2.05 | 5420.1 | 1033.6 | 350.4 | 771.3 |
| Stoker firing refit | 1 | .740 | 2.54 | 4418.7 | 1327.5 | 541.9 | 784.4 |
| Coal/water slurry | 1 | .750 | 3.00 | 2928.1 | 1547.0 | 350.4 | 709.9 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2375.5 | 1735.4 | 278.0 | 602.8 |
| Low Btu gasifier refit | 1 | .652 | 2.54 | 4897.5 | 1481.6 | 323.2 | 1067.6 |
| Packaged shell stoker | 1 | .740 | 2.54 | 4831.2 | 1327.5 | 541.9 | 784.4 |
| Packaged shell FBC | 1 | .780 | 2.05 | 4837.0 | 1043.2 | 350.4 | 776.5 |
| Field erected stoker | 1 | .780 | 2.54 | 7677.2 | 1259.4 | 539.8 | 749.5 |
| Field erected FBC | 1 | .800 | 2.05 | 7229.9 | 891.1 | 407.0 | 769.7 |
| Pulverized coal boiler | 1 | .800 | 2.05 | 8942.1 | 891.1 | 602.7 | 801.6 |
| Circulating FBC | 1 | .810 | 2.05 | 8554.6 | 978.8 | 348.3 | 804.5 |

| AIR FORCE PROJECT | | | | | | PRIVATE PROJECT | |
|------------------------|--|------------------------|-------------------------------|---------------------------|-----------------------------------|-------------------------------|---------------------------|
| | | | LIFE CYCLE COST, | DISCOUNTED | | LIFE CYCLE COST, | |
| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO | PAYBACK PERIOD, yr | DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 35,046 | -- | | | |
| #2 Oil fired boiler | -- | -- | 0 | -- | | | |
| #6 Oil fired boiler | -- | -- | 32,350 | 1.000 | --- Existing system, primary fuel | | |
| Micronized coal refit | Not applicable because of space limitations | | | | | | |
| Slagging burner refit | Not applicable because of space limitations | | | | | | |
| Modular FBC refit | Not applicable because of space limitations | | | | | | |
| Stoker firing refit | Not applicable because existing boiler was designed for #6 oil | | | | | | |
| Coal/water slurry | 1 | 20,143 | 25,537 | 1.267 | 10.1 | 27,686 | 1.168 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | Not applicable because of space limitations | | | | | | |
| Packaged shell stoker | Not applicable because of space limitations | | | | | | |
| Packaged shell FBC | Not applicable because of space limitations | | | | | | |
| Field erected stoker | Not applicable because of space limitations | | | | | | |
| Field erected FBC | Not applicable because of space limitations | | | | | | |
| Pulverized coal boiler | Not applicable because of space limitations | | | | | | |
| Circulating FBC | Not applicable because of space limitations | | | | | | |

NAUSCOM AFE: 1 X 50 MBtu/hr. FUEL REAL ESCALATION - AEO 1987

Total steam output = 50.0 MBtu/hr

Boiler capacity factor = .883

Number of units for refit = 1

Hydrated lime price (\$/ton) = 40.00

Ash disposal price (\$/ton) = 10.00

Electric price (cents/kWh) = 6.10

Labor rate (k\$/yr) = 33.00

Limestone price (\$/ton) = 20.00

FUEL PRICES

Natural gas price (\$/MBtu) = 3.50

#2 Oil price (\$/MBtu) = .00

#6 Oil price (\$/MBtu) = 3.67

OPTIONS

Soot blower multiplier = .0

Tube bank mod multiplier = 1.0

Bottom ash pit multiplier = 1.0

SO2 control multiplier = 1.0

LIMESTONE/LIME

Inert fraction = 05

COAL PROPERTIESR.O.M. Stoker

Ash fraction = .080 .080

Sulfur fraction = .020 .020

HHV (Btu/lb) = 12800. 13600.

FUEL PRICES

R.O.M. coal (\$/MBtu) = 2.05

Stoker coal (\$/MBtu) = 2.34

Coal/H2O mix (\$/MBtu) = 3.00

Coal/oil mix (\$/MBtu) = 3.50

Primary fuel is 1

#6 FUEL OIL

1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988

Gen infla index (1987 to base yr) = 1.040

Gas infla index (1988 to base yr) = 1.000

Oil infla index (1988 to base yr) = 1.000

Coal infla index (1988 to base yr) = 1.000

Project start year = 1990

Project life (yr) = 30

Depreciation life (yr) = 15

General inflation rate (X/yr) = 0

Type of gas escalation = egas

Type of oil escalation = eoil

Type of coal escalation = ecoal

Discount rate (X/yr) = 10

Rate of return on invest (X/yr) = 17

Amount of working capital (month) = 2

Federal income tax rate (X) = 34

Local prop tax (& insur) rate (X) = 2

| | | <u>REAL ESCALATION RATE (X/yr)</u> | | | |
|-------------|---------------------|------------------------------------|-------|-------|----------|
| | <u>TYPE OF FUEL</u> | 1988 | 1990 | 1995 | 2000 AND |
| <u>FUEL</u> | <u>ESCALATION</u> | -1990 | -1995 | -2000 | BEYOND |
| Gas | egas | 2.28 | 4.70 | 5.49 | 2.75 |
| Oil | eoil | .17 | 4.16 | 5.55 | 2.77 |
| Coal | ecoal | 1.46 | 1.76 | 1.61 | .81 |

4:28 PM Oct 19, 1988

WANSBORN AFB: 1 X 50 MBtu/hr. FUEL REAL ESCALATION = AEO 1987

Total steam output = 50.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .883

Primary fuel = #6 FUEL OIL

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | OTHER O & M k\$ |
| | | | | | k\$ | k\$ | k\$ |
| Natural gas boiler | -- | .800 | 3.50 | .0 | 1692.0 | 185.4 | 494.9 |
| #2 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #6 Oil fired boiler | -- | .800 | 3.67 | .0 | 1774.2 | 185.4 | 494.9 |
| Micronized coal refit | 1 | .800 | 2.05 | 2887.4 | 991.1 | 368.2 | 814.6 |
| Slagging burner refit | 1 | .800 | 2.05 | 4775.9 | 991.1 | 368.2 | 814.6 |
| Modular FBC refit | 1 | .780 | 2.05 | 5420.1 | 1003.6 | 350.4 | 771.3 |
| Stoker firing refit | 1 | .740 | 2.54 | 4418.7 | 1327.5 | 541.9 | 784.4 |
| Coal/water slurry | 1 | .750 | 3.00 | 2928.1 | 1547.0 | 350.4 | 709.9 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2375.5 | 1735.4 | 278.0 | 602.8 |
| Low Btu gasifier refit | 1 | .659 | 2.54 | 4997.5 | 1491.6 | 323.2 | 1067.6 |
| Packaged shell stoker | 1 | .740 | 2.54 | 4931.2 | 1327.5 | 541.9 | 784.4 |
| Packaged shell FBC | 1 | .780 | 2.05 | 4837.0 | 1043.2 | 350.4 | 776.5 |
| Field erected stoker | 1 | .780 | 2.54 | 7877.2 | 1259.4 | 539.8 | 749.5 |
| Field erected FBC | 1 | .800 | 2.05 | 7229.0 | 991.1 | 407.0 | 789.7 |
| Pulverized coal boiler | 1 | .800 | 2.05 | 8942.1 | 991.1 | 602.7 | 801.6 |
| Circulating FBC | 1 | .810 | 2.05 | 8554.6 | 978.8 | 348.3 | 804.5 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|--|------------------|-------------------|--------------------------------|------------------------------------|------------------|--------------------------------|
| | | | LIFE CYCLE COST, | DISCOUNTED BENEFIT/ COST RATIO | DISCOUNTED PAYBACK PERIOD, yr | LIFE CYCLE COST, | DISCOUNTED BENEFIT/ COST RATIO |
| | | | AS SPENT | | | AS SPENT | |
| | | | k\$ | | | k\$ | |
| Natural gas boiler | -- | -- | 26,484 | -- | | | |
| #2 Oil fired boiler | -- | -- | 0 | -- | | | |
| #6 Oil fired boiler | -- | -- | 26,182 | 1.000 | ---- Existing system, primary fuel | | |
| Micronized coal refit | Not applicable because of space limitations | | | | | | |
| Slagging burner refit | Not applicable because of space limitations | | | | | | |
| Modular FBC refit | Not applicable because of space limitations | | | | | | |
| Stoker firing refit | Not applicable because existing boiler was designed for #6 oil | | | | | | |
| Coal/water slurry | 1 | 20,143 | 25,211 | 1.035 | 23.6 | 27,433 | .934 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | Not applicable because of space limitations | | | | | | |
| Packaged shell stoker | Not applicable because of space limitations | | | | | | |
| Packaged shell FBC | Not applicable because of space limitations | | | | | | |
| Field erected stoker | Not applicable because of space limitations | | | | | | |
| Field erected FBC | Not applicable because of space limitations | | | | | | |
| Pulverized coal boiler | Not applicable because of space limitations | | | | | | |
| Circulating FBC | Not applicable because of space limitations | | | | | | |

RAMSBOOM APP: 1 X 50 MBtu/hr. FUEL REAL ESCALATION = ZERO

Total steam output = 50.0 MBtu/hr

Boiler capacity factor = .883

Number of units for refit = 1

Hydrated lime price (\$/ton) = 40.00

Ash disposal price (\$/ton) = 10.00

Electric price (cents/kWh) = 6.10

Labor rate (k\$/yr) = 35.00

Limestone price (\$/ton) = 20.00

FUEL PRICES

Natural gas price (\$/MBtu) = 3.50

#2 Oil price (\$/MBtu) = .50

#6 Oil price (\$/MBtu) = 3.67

OPTIONS

Soot blower multiplier = .0

Tube bank mod multiplier = 1.0

Bottom ash pit multiplier = 1.0

SO2 control multiplier = 1.0

LIMESTONE/LIME

Inert fraction = .05

COAL PROPERTIESR.O.M. Stoker

Ash fraction = .080 .080

Sulfur fraction = .020 .020

HHV (Btu/lb) = 12800. 13000.

FUEL PRICES

R.O.M. coal (\$/MBtu) = 2.05

Stoker coal (\$/MBtu) = 2.54

Coal/H2O mix (\$/MBtu) = 3.00

Coal/oil mix (\$/MBtu) = 3.50

Primary fuel is 1

#6 FUEL OIL

1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988

Gen infla index (1987 to base yr) = 1.040

Gas infla index (1988 to base yr) = 1.000

Oil infla index (1988 to base yr) = 1.000

Coal infla index (1988 to base yr) = 1.000

Project start year = 1990

Project life (yr) = 30

Depreciation life (yr) = 15

General inflation rate (I/yr) = 0

Type of gas escalation = zero

Type of oil escalation = zero

Type of coal escalation = zero

Discount rate (I/yr) = 10

Rate of return on invest (I/yr) = 17

Amount of working capital (month) = 2

Federal income tax rate (I) = 34

Local prop tax (& insur) rate (I) = 2

| | | REAL ESCALATION RATE (I/YR) | | | |
|------|----------------------------|-----------------------------|-------|-------|--------------------|
| FUEL | TYPE OF FUEL ESCALATION | 1988 | 1990 | 1995 | 2000 AND BEYOND |
| | | -1990 | -1995 | -2000 | |
| Gas | zero | 0 | 0 | 0 | 0 |
| Oil | zero | 0 | 0 | 0 | 0 |
| Coal | zero | 0 | 0 | 0 | 0 |

4:31 PM Oct 19, 1988

MANSCOM AFB: 1 X 50 MBtu/hr. FUEL REAL ESCALATION = ZERO

Total steam output = 50.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .883

Primary fuel = #6 FUEL OIL

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | OTHER O & M k\$ |
| Natural gas boiler | -- | .800 | 3.50 | .0 | 1692.0 | 165.4 | 494.9 |
| #2 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #6 Oil fired boiler | -- | .800 | 3.67 | .0 | 1774.2 | 165.4 | 494.9 |
| Micronized coal refit | 1 | .800 | 2.05 | 2087.4 | 991.1 | 368.2 | 814.6 |
| Slagging burner refit | 1 | .800 | 2.05 | 4775.9 | 991.1 | 368.2 | 814.6 |
| Modular FBC refit | 1 | .790 | 2.05 | 5420.1 | 1003.5 | 350.4 | 771.3 |
| Stoker firing refit | 1 | .740 | 2.54 | 4418.7 | 1327.5 | 541.9 | 764.4 |
| Coal/water slurry | 1 | .750 | 3.00 | 2928.1 | 1547.0 | 350.4 | 709.9 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2375.5 | 1735.4 | 270.0 | 602.8 |
| Low Btu gasifier refit | 1 | .659 | 2.54 | 4997.5 | 1491.6 | 323.2 | 1067.6 |
| Packaged shell stoker | 1 | .740 | 2.54 | 4931.2 | 1327.5 | 541.9 | 764.4 |
| Packaged shell FBC | 1 | .760 | 2.05 | 4837.0 | 1043.2 | 350.4 | 776.5 |
| Field erected stoker | 1 | .780 | 2.54 | 7877.2 | 1259.4 | 539.8 | 749.5 |
| Field erected FBC | 1 | .800 | 2.05 | 7229.0 | 991.1 | 407.0 | 769.7 |
| Pulverized coal boiler | 1 | .800 | 2.05 | 8942.1 | 991.1 | 602.7 | 801.6 |
| Circulating FBC | 1 | .810 | 2.05 | 8554.6 | 978.8 | 348.3 | 804.5 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|--|------------------|---------------------|---------------------|------------------------------------|---------------------|---------------------|
| | | | LIFE CYCLE COST, | BENEFIT/ COST RATIO | PAYBACK PERIOD, Yr | LIFE CYCLE COST, | BENEFIT/ COST RATIO |
| | | | DISCOUNTED AS SPENT | | | DISCOUNTED AS SPENT | |
| | | | k\$ | | | k\$ | |
| Natural gas boiler | -- | -- | 18,517 | -- | | | |
| #2 Oil fired boiler | -- | -- | 0 | -- | | | |
| #6 Oil fired boiler | -- | -- | 19,158 | 1.000 | <--- Existing system, primary fuel | | |
| Micronized coal refit | Not applicable because of space limitations | | | | | | |
| Slagging burner refit | Not applicable because of space limitations | | | | | | |
| Modular FBC refit | Not applicable because of space limitations | | | | | | |
| Stoker firing refit | Not applicable because existing boiler was designed for #6 oil | | | | | | |
| Coal/water slurry | 1 | 20,143 | 23,137 | .828 | >31 | 25,217 | .760 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | Not applicable because of space limitations | | | | | | |
| Packaged shell stoker | Not applicable because of space limitations | | | | | | |
| Packaged shell FBC | Not applicable because of space limitations | | | | | | |
| Field erected stoker | Not applicable because of space limitations | | | | | | |
| Field erected FBC | Not applicable because of space limitations | | | | | | |
| Pulverized coal boiler | Not applicable because of space limitations | | | | | | |
| Circulating FBC | Not applicable because of space limitations | | | | | | |

ANDREWS AFB: MAC

1. BACKGROUND

Andrews AFB is located near Washington, D.C. There are three steam plants on the base, all of which were upgraded in some manner in 1985. The specifics of this upgrade effort are not known and probably should be investigated. Two of these plants may be large enough to get some consideration for coal conversion. Each steam plant consists of water-tube boilers producing saturated steam at 100 psig.

All boilers, with the exception of three built after 1964 (see the lists that follow), are designed for bituminous coal. Residual oil (No. 6) is the primary fuel for all the boilers, and there is apparently no secondary fuel. Some coal storage silos and receiving hoppers are still on site.

Data are inconsistent with regard to annual fuel use. Data for plant No. 1515 average fuel consumption range from 22 to 49 MBtu/h, with the larger value reported by C. H. Guernsey and Co. The data for plant No. 1732 range from 15 to 40 MBtu/h, with the smaller value reported by C. H. Guernsey and Co. It is assumed that plant No. 1515 and plant No. 1732 are interconnected.

2. HEATING PLANT UNITS

Heating Plant No. 1515:

2 x 59.8 MBtu/h, Bigelow, 1958
2 x 29.9 and 15.9 MBtu/h, Union Iron Works, 1946

Heating Plant No. 1732:

3 x 33.5 MBtu/h; Keeler Co.; 2-1961, 1-1965

Heating Plant No. 3409:

2 x 16 MBtu/h, Keeler Co., 1971
3 x 15 MBtu/h, Keeler Co., 1960

3. IDEAL CAPACITY FACTOR ANALYSIS

Maximum possible load factors as a function of project size are given below. Load information was calculated assuming two boiler plants (No. 1515 and No. 1732) are interconnected.

Plant Nos. 1515 and 1732
interconnected

| Fuel input (MBtu/h) | CY 1985 ideal capacity factor | FY 1986 ideal capacity factor |
|---------------------------|--|--|
| 30 | 0.92 | 0.73 |
| 50 | 0.76 | 0.57 |
| 70 | 0.67 | 0.49 |
| 90 | 0.60 | 0.43 |
| 120 | 0.51 | 0.39 |

4. ENERGY PRICES

FY 1986 Price Data

| | <u>Average</u> | <u>Year end</u> |
|----------------|----------------|-----------------|
| Electricity | 5.4¢/kWh | |
| Residual oil | \$3.8/MBtu | \$2.6/MBtu ? |
| Distillate oil | \$5.9/MBtu | \$3.3/MBtu ? |

C. H. Guernsey and Co. Survey:

Electricity = 5.0¢/kWh
Residual oil = \$4.67/MBtu
Distillate oil = \$5.56/MBtu

5. COAL PROPERTIES AND PRICES

| | <u>Stoker</u> | <u>ROM</u> |
|-------------------------------------|---------------------|---------------------|
| Origin | Clearfield Co., Pa. | Clearfield Co., Pa. |
| HHV, Btu/lb | 13,000 | 12,800 |
| % Ash | 10 | 13 |
| % Sulfur | 2 | 2 |
| % Nitrogen | 1.5 | 1.5 |
| Ash-softening temperature, °F | 2450 | 2450 |
| Swelling index | 8-9 | 8-9 |
| Top size, in. | 1 1/4 | 2 |
| Bottom size, in. | 3/8 | 0 |
| Fines, % | 15 | |
| Grindability index | 90+ | 90+ |
| Cost at mine, \$/ton | 40 | 30 |
| Delivered cost, \$/ton | 57 | 47 |
| Energy cost, \$/10 ⁶ Btu | 2.19 | 1.84 |

6. ENVIRONMENTAL REGULATIONS

No solid-fuel-burning plant smaller than 35 MBtu/h is allowed.

6.1 Air Pollution Emission Limits for New Sources

SO₂. No emission limits for boilers <100 MBtu/h; for boilers >100 MBtu/h: FBC - 90% reduction to meet limit of 1.2 lb/MBtu; emerging technology - 50% reduction to meet limit of 0.6 lb/MBtu.

NO_x. No emission limits for boilers <100 MBtu/h; for boilers >100 MBtu/h: spreader stoker and FBC - 0.6 lb/MBtu; pulverized coal - 0.7 lb/MBtu.

Particulates. For boilers >100 MBtu/h: 0.05 lb/MBtu; for 60 MBtu/h - 0.25 lb/MBtu.

6.2 Coal-Pile Runoff

Limit: Total suspended solids - 50 mg/L.

6.3 Ash Disposal

Ashes are classified as nonhazardous industrial solid waste and may be disposed of in any approved sanitary landfill.

7. OTHER CONSIDERATIONS

Andrews apparently uses a lot of electricity: 100,235 MWh in FY 1986, an average of about 11.4 MW. Residual oil use in FY 1986 was ~568,000 MBtu, an average of about 65 MBtu/h. The highest monthly steam load is about 150 MBtu/h.

A previous study was done (Roy Weston Study) to examine connecting the three boiler plants and building a single coal plant for \$75M. Andrews has also been the subject of a coal-oil-mixture study.

This base is within range of anthracite sources.

8. COAL-CONVERSION PROJECT OUTLOOK

Because load factors are low, only conversion of one 60-MBtu/h output (~75-MBtu/h fuel input) boiler would be practical. The overall load factor for this size of project is expected to be about 50%, assuming a 90% equipment availability, and the two plants are interconnected.

8.1 Effect of Environmental Regulations on Selection of Combustion Technologies

SO₂ and NO_x. Any of the combustion technologies being considered could be employed without requiring any measures for SO₂ or NO_x reduction because the proposed conversion project is smaller than 100 MBtu/h.

Particulates. Bag filters or electrostatic precipitators would be required to comply with the particulate emission limits.

8.2 Physical Space and Aesthetics

Heating Plant. The existing boiler plant was originally designed for coal. There is space available for reinstalling coal-combustion equipment at the existing boiler or for construction of a new boiler at another site on base.

Coal-Handling Equipment. The coal-storage silo and the outside receiving hopper and silo are still in place at plant 1515. There is space available for installing the other coal-handling equipment.

Coal Pile. There is space available for a coal pile near the existing boiler plant 1515 or at a new site on base.

8.3 Technical Risk of Combustion Technologies

The least technical risk would be for refit of stoker firing to one of the existing coal-designed boilers or installation of a new stoker-fired boiler. The other technologies would have greater technical risks because of lack of operating experience, and all of them would be of the same order because the existing boilers are designed for coal-firing.

9. COGENERATION PROJECT OUTLOOK

The prospects for a coal-fired cogeneration system appear to be somewhat marginal. Andrews has a high minimum monthly average electric load, 7.8 MWe, but the price of electricity is only moderately high (5¢/kWh). Another negative factor is the relatively low average heat load compared to the electric load, so that it is difficult to achieve a high overall load factor for a cogeneration plant. Based on the FY 1986 energy-use data, a cogeneration plant with a boiler rating of 68 MBtu/h output and a 5-MWe turbine-generator would have an electrical power capacity factor of 90% and a peak thermal output of 50 MBtu/h, with a thermal energy capacity factor of about 50% if used as a baseload heating plant. To achieve as high an efficiency as practical, a 1450-psia, 950°F water-tube boiler should be employed for such a cogeneration plant.

The information provided by the base energy-use questionnaire indicated that natural gas is not available at the base.

10. INPUT AND LCC SUMMARY SPREADSHEETS

ANDREWS AFB: 1 X 60 MBtu/hr. ECONOMIC PARAMETERS - NOMINAL VALUES

Total steam output = 60.0 MBtu/hr
 Boiler capacity factor = .504
 Number of units for refit = 1
 Hydrated lime price (\$/ton) = 40.00
 Ash disposal price (\$/ton) = 10.00
 Electric price (cents/kWh) = 5.00
 Labor rate (k\$/yr) = 35.00
 Limestone price (\$/ton) = 20.00

COAL PROPERTIES

| | R.O.M. | Stoker |
|-----------------|--------|--------|
| Ash fraction | .130 | .100 |
| Sulfur fraction | .020 | .020 |
| HHV (Btu/lb) | 12800. | 13000. |

FUEL PRICES
 Natural gas price (\$/MBtu) = .00
 #2 Oil price (\$/MBtu) = .00
 #6 Oil price (\$/MBtu) = 3.67

OPTIONS
 Soot blower multiplier = .0
 Tube bank mod multiplier = .0
 Bottom ash pit multiplier = 1.0
 SO2 control multiplier = .0

LIMESTONE/LIME
 Inert fraction = .05

FUEL PRICES
 R.O.M. coal (\$/MBtu) = 1.84
 Stoker coal (\$/MBtu) = 2.19
 Coal/H2O mix (\$/MBtu) = 3.00
 Coal/oil mix (\$/MBtu) = 3.50

Primary fuel is 1
 #6 FUEL OIL
 1-#6 OIL, 2-#2 OIL, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988
 Gen infla index (1987 to base yr) = 1.040
 Gas infla index (1988 to base yr) = 1.000
 Oil infla index (1988 to base yr) = 1.000
 Coal infla index (1988 to base yr) = 1.000
 Project start year = 1990
 Project life (yr) = 30
 Depreciation life (yr) = 15
 General inflation rate (I/yr) = 0
 Type of gas escalation = egas
 Type of oil escalation = eoil
 Type of coal escalation = ecoal
 Discount rate (I/yr) = 10
 Rate of return on invest (I/yr) = 17
 Amount of working capital (month) = 2
 Federal income tax rate (I) = 34
 Local prop tax (& insur) rate (I) = 2

| | | REAL ESCALATION RATE (I/yr) | | | |
|------|----------------------------|-----------------------------|-------|-------|--------------------|
| FUEL | TYPE OF FUEL ESCALATION | 1988 | 1990 | 1995 | 2000 AND BEYOND |
| | | -1990 | -1995 | -2000 | |
| Gas | egas | 3.89 | 8.87 | 5.77 | 5.77 |
| Oil | eoil | 4.86 | 7.87 | 4.16 | 4.16 |
| Coal | ecoal | 1.16 | 2.31 | 1.19 | 1.19 |

9:42 AM Oct 18, 1988

ANDREWS AFB: 1 X 60 Mbtu/hr. ECONOMIC PARAMETERS - NOMINAL VALUES

Total steam output = 60.0 Mbtu/hr

Cost base year = 1988

Boiler capacity factor = .504

Primary fuel = #6 FUEL OIL

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/Mbtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | OTHER O & M k\$ |
| Natural gas boiler | -- | .800 | .30 | .0 | .0 | .0 | .0 |
| #2 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #6 Oil fired boiler | -- | .800 | 3.67 | .0 | 1215.2 | 182.9 | 493.1 |
| Micronized coal refit | 1 | .800 | 1.84 | 2882. | 809.3 | 393.3 | 863.7 |
| Slagging burner refit | 1 | .800 | 1.84 | 4982.0 | 809.3 | 393.3 | 863.7 |
| Modular FBC refit | 1 | .790 | 1.84 | 5725.4 | 817.0 | 374.2 | 848.5 |
| Stoker firing refit | 1 | .780 | 2.19 | 3377.7 | 783.3 | 374.2 | 838.8 |
| Coal/water slurry | 1 | .750 | 3.00 | 2803.5 | 1059.6 | 374.2 | 566.3 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2309.9 | 1188.7 | 298.0 | 536.9 |
| Low Btu gasifier refit | 2 | .679 | 2.19 | 5804.5 | 854.9 | 345.1 | 865.4 |
| Packaged shell stoker | 2 | .780 | 2.19 | 5060.9 | 783.3 | 374.2 | 729.3 |
| Packaged shell FBC | 2 | .780 | 1.84 | 6250.7 | 841.3 | 374.2 | 741.7 |
| Field erected stoker | 1 | .800 | 2.19 | 7261.2 | 725.2 | 371.9 | 828.5 |
| Field erected FBC | 1 | .800 | 1.84 | 7958.0 | 809.3 | 434.6 | 848.3 |
| Pulverized coal boiler | 1 | .820 | 1.84 | 8459.5 | 594.4 | 439.1 | 678.0 |
| Circulating FBC | 1 | .810 | 1.84 | 9358.8 | 601.8 | 371.9 | 702.9 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|---------------|------------------|--|---------------------|------------------------------------|--|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO | DISCOUNTED PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 0 | -- | | | |
| #2 Oil fired boiler | -- | -- | 0 | -- | | | |
| #6 Oil fired boiler | -- | -- | 23,980 | 1.000 | <--- Existing system, primary fuel | | |
| Micronized coal refit | 1 | 12,935 | 16,762 | 1.431 | 7.5 | 18,640 | 1.287 |
| Slagging burner refit | 1 | 12,935 | 18,497 | 1.298 | 11.7 | 21,445 | 1.118 |
| Modular FBC refit | 1 | 13,098 | 18,895 | 1.269 | 12.8 | 22,216 | 1.079 |
| Stoker firing refit | 1 | 13,406 | 18,230 | 1.315 | 9.8 | 20,390 | 1.176 |
| Coal/water slurry | 1 | 13,797 | 19,809 | 1.211 | 12.0 | 21,637 | 1.108 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | 2 | 15,014 | 22,612 | 1.061 | 23.6 | 26,077 | .920 |
| Packaged shell stoker | 2 | 13,406 | 20,342 | 1.179 | 15.5 | 23,381 | 1.026 |
| Packaged shell FBC | 2 | 13,615 | 20,282 | 1.182 | 16.1 | 23,898 | 1.003 |
| Field erected stoker | 1 | 12,736 | 20,998 | 1.142 | 18.4 | 25,126 | .954 |
| Field erected FBC | 1 | 12,935 | 21,231 | 1.130 | 19.4 | 25,719 | .932 |
| Pulverized coal boiler | 1 | 12,619 | 21,753 | 1.102 | 21.2 | 26,486 | .905 |
| Circulating FBC | 1 | 12,775 | 22,324 | 1.074 | 23.4 | 27,608 | .869 |

ANDREWS APP: 1 X 60 MBtu/hr. FUEL, REAL ESCALATION - AFD 1987

Total steam output = 60.0 MBtu/hr

Boiler capacity factor = .584

Number of units for refit = 1

Hydrated lime price (\$/ton) = 40.00

Ash disposal price (\$/ton) = 10.00

Electric price (cents/kWh) = 5.00

Labor rate (k\$/yr) = 35.00

Limestone price (\$/ton) = 20.00

FUEL PRICES

Natural gas price (\$/MBtu) = .00

#2 Oil price (\$/MBtu) = .00

#6 Oil price (\$/MBtu) = 3.67

OPTIONS

Soot blower multiplier = .0

Tube bank mod multiplier = .0

Bottom ash pit multiplier = 1.0

SO2 control multiplier = .0

LIMESTONE/LIME

Inert fraction = .05

COAL PROPERTIESR.O.M. Stoker

Ash fraction = .130 .100

Sulfur fraction = .020 .030

HHV (Btu/lb) = 12800. 13000.

FUEL PRICES

R.O.M. coal (\$/MBtu) = 1.84

Stoker coal (\$/MBtu) = 2.10

Coal/H2O mix (\$/MBtu) = 3.00

Coal/oil mix (\$/MBtu) = 3.50

Primary fuel is 1

#6 FUEL OIL

1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988

Gen infla index (1987 to base yr) = 1.040

Gas infla index (1988 to base yr) = 1.000

Oil infla index (1988 to base yr) = 1.000

Coal infla index (1988 to base yr) = 1.000

Project start year = 1990

Project life (yr) = 30

Depreciation life (yr) = 15

General inflation rate (I/yr) = 0

Type of gas escalation = egas

Type of oil escalation = eoil

Type of coal escalation = ecoal

Discount rate (I/yr) = 10

Rate of return on invest (I/yr) = 17

Amount of working capital (month) = 2

Federal income tax rate (I) = 34

Local prop tax (& insur) rate (I) = 2

REAL ESCALATION RATE (I/yr)

| FUEL | TYPE OF FUEL ESCALATION | 1988 | 1990 | 1995 | 2000 AND BEYOND |
|------|----------------------------|-------|-------|-------|--------------------|
| | | -1990 | -1995 | -2000 | |
| Gas | egas | 2.28 | 4.70 | 5.49 | 2.75 |
| Oil | eoil | .17 | 4.16 | 5.55 | 2.77 |
| Coal | ecoal | 1.46 | 1.76 | 1.61 | .81 |

4:03 PM Oct 13, 1988

ANDREWS AFB: 1 X 60 MBtu/hr. FUEL REAL ESCALATION ~ AFO 1987

Total steam output = 60.0 MBtu/hr

Cost base year ~ 1988

Boiler capacity factor = .504

Primary fuel ~ #6 FUEL OIL

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | OTHER O & M k\$ |
| Natural gas boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #2 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #6 Oil fired boiler | -- | .800 | 3.67 | .0 | 1215.2 | 182.9 | 493.1 |
| Micronized coal refit | 1 | .800 | 1.84 | 2882.7 | 609.3 | 393.3 | 663.7 |
| Slagging burner refit | 1 | .800 | 1.84 | 4982.0 | 609.3 | 393.3 | 663.7 |
| Modular FBC refit | 1 | .780 | 1.84 | 5725.4 | 617.0 | 374.2 | 648.5 |
| Stoker firing refit | 1 | .760 | 2.19 | 3377.7 | 763.3 | 374.2 | 636.8 |
| Coal/water slurry | 1 | .750 | 3.00 | 2603.5 | 1059.6 | 374.2 | 566.3 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2309.9 | 1188.7 | 298.0 | 536.9 |
| Low Btu gasifier refit | 2 | .679 | 2.19 | 5804.5 | 354.9 | 345.1 | 865.4 |
| Packaged shell stoker | 2 | .760 | 2.19 | 5060.9 | 763.3 | 374.2 | 729.3 |
| Packaged shell FBC | 2 | .760 | 1.84 | 6250.7 | 641.3 | 374.2 | 741.7 |
| Field erected stoker | 1 | .600 | 2.19 | 7261.2 | 725.2 | 371.9 | 628.5 |
| Field erected FBC | 1 | .800 | 1.84 | 7668.0 | 609.3 | 434.6 | 648.3 |
| Pulverized coal boiler | 1 | .820 | 1.84 | 8459.3 | 594.4 | 439.1 | 678.0 |
| Circulating FBC | 1 | .810 | 1.84 | 9558.8 | 601.8 | 371.9 | 702.9 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|---------------|------------------|--|--------------------|------------------------------------|--|--------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/COST RATIO | PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/COST RATIO |
| Natural gas boiler | -- | -- | 0 | -- | | | |
| #2 Oil fired boiler | -- | -- | 0 | -- | | | |
| #6 Oil fired boiler | -- | -- | 19,755 | 1.000 | <--- Existing system, primary fuel | | |
| Micronized coal refit | 1 | 12,935 | 16,665 | 1.185 | 12.1 | 18,540 | 1.066 |
| Slagging burner refit | 1 | 12,935 | 18,400 | 1.974 | 20.4 | 21,348 | .925 |
| Modular FBC refit | 1 | 13,098 | 18,796 | 1.051 | 22.0 | 22,115 | .893 |
| Stoker firing refit | 1 | 13,406 | 18,109 | 1.091 | 17.8 | 20,260 | .975 |
| Coal/water slurry | 1 | 13,787 | 19,641 | 1.006 | 29.3 | 21,464 | .920 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | 2 | 15,014 | 22,476 | .879 | >31 | 25,938 | .762 |
| Packaged shell stoker | 2 | 13,406 | 20,221 | .977 | >31 | 23,256 | .849 |
| Packaged shell FBC | 2 | 13,615 | 20,180 | .979 | >31 | 23,794 | .830 |
| Field erected stoker | 1 | 12,736 | 20,882 | .946 | >31 | 25,007 | .790 |
| Field erected FBC | 1 | 12,935 | 21,134 | .935 | >31 | 25,620 | .771 |
| Pulverized coal boiler | 1 | 12,619 | 21,659 | .912 | >31 | 26,389 | .749 |
| Circulating FBC | 1 | 12,775 | 22,228 | .889 | >31 | 27,509 | .718 |

4:03 PM Oct 18, 1988

AMURENS AFB: 1 X 60 MBtu/hr. FUEL REAL ESCALATION = ZERO

Total steam output = 60.0 MBtu/hr

Boiler capacity factor = .504

Number of units for refit = 1

Hydrated lime price (\$/ton) = 40.00

Ash disposal price (\$/ton) = 10.00

Electric price (cents/kWh) = 5.00

Labor rate (\$/hr) = 35.00

Limestone price (\$/ton) = 20.00

FUEL PRICES

Natural gas price (\$/MBtu) = .00

#2 Oil price (\$/MBtu) = .00

#6 Oil price (\$/MBtu) = 3.67

OPTIONS

Soot blower multiplier = .0

Tube bank mod multiplier = .0

Bottom ash pit multiplier = 1.0

SO2 control multiplier = .0

LIMESTONE/LIME

Inert fraction = .05

COAL PROPERTIESR.O.M. Stoker

Ash fraction = .130 .100

Sulfur fraction = .020 .020

HHV (Btu/lb) = 12800. 13000.

FUEL PRICES

R.O.M. coal (\$/MBtu) = 1.84

Stoker coal (\$/MBtu) = 2.19

Coal/H2O mix (\$/MBtu) = 3.00

Coal/oil mix (\$/MBtu) = 3.50

Primary fuel is 1

#5 FUEL OIL

1-#5 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988

Gen infla index (1987 to base yr) = 1.040

Gas infla index (1988 to base yr) = 1.000

Oil infla index (1988 to base yr) = 1.000

Coal infla index (1988 to base yr) = 1.000

Project start year = 1990

Project life (yr) = 30

Depreciation life (yr) = 15

General inflation rate (I/yr) = 0

Type of gas escalation = zero

Type of oil escalation = zero

Type of coal escalation = zero

Discount rate (I/yr) = 10

Rate of return on invest (I/yr) = 17

Amount of working capital (month) = 2

Federal income tax rate (I) = 34

Local prop tax (& insur) rate (I) = 2

| | | <u>REAL ESCALATION RATE (I/yr)</u> | | | |
|-------------|--------------------------------|------------------------------------|-------|-------|----------|
| <u>FUEL</u> | <u>TYPE OF FUEL ESCALATION</u> | 1988 | 1990 | 1995 | 2000 AND |
| | | -1990 | -1995 | -2000 | BEYOND |
| Gas | zero | 0 | 0 | 0 | 0 |
| Oil | zero | 0 | 0 | 0 | 0 |
| Coal | zero | 0 | 0 | 0 | 0 |

1:37 PM Oct 19, 1988

ANDREWS AFB: 1 X 60 MBtu/hr. FUEL REAL ESCALATION = ZERO

Total steam output = 60.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .504

Primary fuel = #6 FUEL OIL

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | OTHER O & M k\$ |
| Natural gas boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #2 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #6 Oil fired boiler | -- | .800 | 3.67 | .0 | 1215.2 | 182.9 | 493.1 |
| Micronized coal refit | 1 | .800 | 1.84 | 2882.7 | 609.3 | 393.3 | 663.7 |
| Slagging burner refit | 1 | .800 | 1.84 | 4982.0 | 609.3 | 393.3 | 663.7 |
| Modular FBC refit | 1 | .790 | 1.84 | 5725.4 | 617.0 | 374.2 | 648.5 |
| Stoker firing refit | 1 | .760 | 2.19 | 3377.7 | 763.3 | 374.2 | 636.8 |
| Coal/water slurry | 1 | .750 | 3.00 | 2603.5 | 1059.6 | 374.2 | 566.3 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2309.9 | 1188.7 | 298.0 | 536.9 |
| Low Btu gasifier refit | 2 | .679 | 2.19 | 3804.5 | 854.9 | 345.1 | 885.4 |
| Packaged shell stoker | 2 | .760 | 2.19 | 5060.9 | 763.3 | 374.2 | 729.3 |
| Packaged shell FBC | 2 | .760 | 1.84 | 6250.7 | 641.3 | 374.2 | 741.7 |
| Field erected stoker | 1 | .800 | 2.19 | 7261.2 | 725.2 | 371.9 | 628.5 |
| Field erected FBC | 1 | .800 | 1.84 | 7988.0 | 609.3 | 434.6 | 648.3 |
| Pulverized coal boiler | 1 | .820 | 1.84 | 8459.5 | 594.4 | 439.1 | 678.0 |
| Circulating FBC | 1 | .810 | 1.84 | 9556.8 | 601.8 | 371.9 | 702.9 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|---------------|------------------|--|---------------------|------------------------------------|--|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO | PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 0 | -- | | | |
| #2 Oil fired boiler | -- | -- | 0 | -- | | | |
| #6 Oil fired boiler | -- | -- | 14,944 | 1.000 | <--- Existing system, primary fuel | | |
| Micronized coal refit | 1 | 12,935 | 15,817 | .945 | >31 | 17,667 | .846 |
| Slagging burner refit | 1 | 12,935 | 17,552 | .851 | >31 | 20,473 | .730 |
| Modular FBC refit | 1 | 13,098 | 17,937 | .833 | >31 | 21,231 | .704 |
| Stoker firing refit | 1 | 13,406 | 17,046 | .877 | >31 | 19,172 | .779 |
| Coal/water slurry | 1 | 13,797 | 18,165 | .823 | >31 | 19,946 | .749 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | 2 | 15,014 | 21,285 | .702 | >31 | 24,713 | .605 |
| Packaged shell stoker | 2 | 13,406 | 19,157 | .780 | >31 | 22,163 | .674 |
| Packaged shell FBC | 2 | 13,615 | 19,287 | .775 | >31 | 22,875 | .653 |
| Field erected stoker | 1 | 12,736 | 19,872 | .752 | >31 | 23,959 | .623 |
| Field erected FBC | 1 | 12,935 | 20,285 | .737 | >31 | 24,747 | .604 |
| Pulverized coal boiler | 1 | 12,619 | 20,831 | .717 | >31 | 25,538 | .585 |
| Circulating FBC | 1 | 12,775 | 21,390 | .699 | >31 | 26,648 | .561 |

4:11 PM Oct 18, 1988

DOVER AFB: MAC

1. BACKGROUND

Dover AFB is located near Dover, Delaware. The four central heating plant boilers are high-temperature, hot-water (414°F, 275-psi) units. All boilers burn No. 6 oil. The three Combustion Engineering units were designed for coal. In CY 1985 average fuel use was about 46 MBtu/h, and the January 1985 average fuel use was 88 MBtu/h. In FY 1986, average fuel input was about 44 MBtu/h. Boiler efficiency at peak load is about 77%.

2. HEATING PLANT UNITS

Heating Plant No. 617:

3 x 50 MBtu/h, Combustion Engineering, 1953
1 x 50 MBtu/h, International Lamont, 1972

3. IDEAL CAPACITY FACTOR ANALYSIS

The ideal capacity factors listed below were calculated from monthly fuel-use data for plant No. 617.

| Fuel input (MBtu/h) | CY 1985 ideal capacity factor | FY 1986 ideal capacity factor |
|---------------------------|--|--|
| 20 | 1.00 | 1.00 |
| 30 | 0.94 | 0.90 |
| 40 | 0.84 | 0.80 |
| 50 | 0.76 | 0.73 |
| 60 | 0.69 | 0.67 |
| 70 | 0.63 | 0.61 |
| 80 | 0.57 | 0.55 |

4. ENERGY PRICES

FY 1986 Price Data:

Electricity = \$16.5/MBtu = 5.6¢/kWh
Distillate = \$5.87/MBtu
Residual = \$5.00/MBtu

C. H. Guernsey and Co. Survey:

Electricity = 6.6¢/kWh
Residual = \$4.67/MBtu

5. COAL PROPERTIES AND PRICES

| | Stoker | ROM |
|-------------------------------|---------------------|---------------------|
| Origin | Clearfield Co., Pa. | Clearfield Co., Pa. |
| HHV, Btu/lb | 13,000 | 12,800 |
| % Ash | 10 | 13 |
| % Sulfur | 2 | 2 |
| % Nitrogen | 1.5 | 1.5 |
| Ash-softening temperature, °F | 2450 | 2450 |
| Swelling index | 8-9 | 8-9 |
| Top size, in. | 1 1/4 | 2 |
| Bottom size, in. | 3/8 | 0 |
| Fines, % | 15 | |
| Grindability index | 90+ | 90+ |
| Cost at mine, \$/ton | 40 | 30 |
| Delivered cost, \$/ton | 57 | 47 |
| Energy cost, \$/10 Btu | 2.19 | 1.84 |

6. ENVIRONMENTAL REGULATIONS

6.1 Air Pollution Emission Limits for New Sources

SO₂. No emission limits for boilers <100 MBtu/h; 1.2 lb/MBtu and 90% reduction for >100 MBtu/h.

NO_x. No emission limits for boilers <100 MBtu/h; 0.6 lb/MBtu for >100 MBtu/h.

Particulates. 0.3 lb/MBtu for boilers 1-100 MBtu/h; 0.05 lb/MBtu for >100 MBtu/h.

6.2 Coal-Pile Runoff

Limit: Total suspended solids - 50 mg/L.

6.3 Ash Disposal

Ashes are classified as "Solid Waste Refuse" and may be disposed of in any approved sanitary landfill. Disposal cost is 45¢/ton.

7. OTHER CONSIDERATIONS

Dover is the current site for a coal-oil-water-mixture demonstration project. Fuel will be supplied by Coaliquid Inc. About \$4 million was spent to alter one boiler and to add peripheral equipment. The altered boiler may be quite ideal for a micronized coal burner system or some other coal technology.

8. COAL-CONVERSION PROJECT OUTLOOK

This is a candidate for conversion of one unit, based on the load data. Also note that one boiler has been reworked for coal-oil-water-mixture firing and may be cheaply converted to some type of 100% coal firing.

If one 50-MBtu/h output (~65-MBtu/h fuel input) unit was converted to coal, the maximum capacity factor would be about 65%. Assuming a 90% equipment availability, an overall capacity factor of about 58% is obtained.

8.1 Effect of Environmental Regulations on Selection of Combustion Technologies

SO₂ and NO_x. Any of the combustion technologies being considered could be employed without requiring any measures for SO₂ or NO_x reduction because the proposed conversion project is smaller than 100 MBtu/h.

Particulates. Bag filters or electrostatic precipitators would be required to comply with the particulate emission limits.

8.2 Physical Space and Aesthetics

Heating Plant. The existing boiler plant was originally designed for coal. There is space available for reinstalling coal combustion equipment at the existing boiler or for construction of a new boiler at another site on base.

Coal-Handling Equipment. There is space available for installing coal-handling equipment at the existing boiler.

Coal Pile. There is space available for a coal pile at the existing boiler plant or at a new site on base.

8.3 Technical Risk of Combustion Technologies

The least technical risk would be for refit of stoker firing to the existing boiler, since it was originally designed for this, or installation of a new stoker-fired boiler. The other technologies would have greater technical risks because of lack of operating experience, and all of them would be of the same order because the existing boiler is designed for coal-firing.

9. COGENERATION PROJECT OUTLOOK

The prospects look interesting for a coal-fired cogeneration system. The minimum monthly average electric load is about 4.7 MWe, and the price of electricity is high (6.6¢/kWh). Based on the FY 1986 energy-use data, a cogeneration plant with a boiler rating of

68-MBtu/h output and a 5-MWe turbine-generator would have an electrical power capacity factor of about 90% and a peak thermal output of 50 MBtu/h, with a thermal energy capacity factor of about 70% if used as a baseload heating plant. A cogeneration plant of this capacity should be near the optimum size for base needs. A water-tube boiler with a steam rating of 1450 psia and 950°F would be the most suitable type of boiler for a high-efficiency cogeneration system.

The information provided by the base energy-use questionnaire indicated that natural gas was not available at the base, and therefore a gas-fired cogeneration system is not an available option.

10. INPUT AND LCC SUMMARY SPREADSHEETS

DOVER AFB: 1 X 50 MBtu/hr. ECONOMIC PARAMETERS - NOMINAL VALUES

| | | |
|---|---------|--|
| Total steam output = 50.0 | MBtu/hr | |
| Boiler capacity factor = .583 | | |
| Number of units for refit = 1 | | |
| Hydrated lime price (\$/ton) = 40.00 | | |
| Ash disposal price (\$/ton) = 10.00 | | |
| Electric price (cents/kWh) = 6.60 | | |
| Labor rate (k\$/yr) = 35.00 | | |
| Limestone price (\$/ton) = 20.00 | | |
| FUEL PRICES | | COAL PROPERTIES |
| Natural gas price (\$/MBtu) = .00 | | R.O.M. Stoker |
| #2 Oil price (\$/MBtu) = .00 | | Ash fraction = .130 .100 |
| #6 Oil price (\$/MBtu) = 3.67 | | Sulfur fraction = .020 .020 |
| | | HHV (Btu/lb) = 12800. 13000. |
| OPTIONS | | FUEL PRICES |
| Scot blower multiplier = .0 | | R.O.M. coal (\$/MBtu) = 1.84 |
| Tube bank mod multiplier = .0 | | Stoker coal (\$/MBtu) = 2.19 |
| Bottom ash pit multiplier = 1.0 | | Coal/H ₂ O mix (\$/MBtu) = 3.00 |
| SO ₂ control multiplier = .3 | | Coal/oil mix (\$/MBtu) = 3.55 |
| LIMESTONE/LIME | | |
| Inert fraction = .05 | | |

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988
 Gen infla index (1987 to base yr) = 1.040
 Gas infla index (1988 to base yr) = 1.000
 Oil infla index (1988 to base yr) = 1.000
 Coal infla index (1988 to base yr) = 1.000
 Project start year = 1990
 Project life (yr) = 30
 Depreciation life (yr) = 15
 General inflation rate (X/yr) = 0
 Type of gas escalation = egas
 Type of oil escalation = eoil
 Type of coal escalation = ecoal
 Discount rate (X/yr) = 10
 Rate of return on invest (X/yr) = 17
 Amount of working capital (month) = 2
 Federal income tax rate (X) = 34
 Local prop tax (& insur) rate (X) = 2

| | | REAL ESCALATION RATE (X/yr) | | | |
|------|----------------------------|-----------------------------|-------|-------|----------|
| FUEL | TYPE OF FUEL ESCALATION | 1988 | 1990 | 1995 | 2000 AND |
| | | -1990 | -1995 | -2000 | BEYOND |
| Gas | egas | 3.89 | 8.87 | 5.77 | 5.77 |
| Oil | eoil | 4.86 | 7.87 | 4.16 | 4.16 |
| Coal | ecoal | 1.16 | 2.31 | 1.19 | 1.19 |

1:14 PM Oct 19, 1988

DOVER AFB: 1 X 50 MBtu/hr. ECONOMIC PARAMETERS - NOMINAL VALUES

Total steam output ~ 50.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .583

Primary fuel = #6 FUEL OIL

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | DISC. COST k\$ |
| Natural gas boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #2 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #6 Oil fired boiler | -- | .800 | 3.67 | .0 | 1171.4 | 165.4 | 484.6 |
| Micronized coal refit | 1 | .800 | 1.84 | 2616.3 | 587.3 | 368.2 | 662.0 |
| Slagging burner refit | 1 | .800 | 1.84 | 4504.8 | 587.3 | 368.2 | 662.0 |
| Modular FBC refit | 1 | .790 | 1.84 | 5173.9 | 594.7 | 350.4 | 642.6 |
| Stoker firing refit | 1 | .760 | 2.19 | 3070.2 | 735.8 | 350.4 | 628.9 |
| Coal/water slurry | 1 | .750 | 3.00 | 2353.1 | 1021.4 | 350.4 | 560.6 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2081.4 | 1145.8 | 279.0 | 532.2 |
| Low Btu gasifier refit | 1 | .679 | 2.19 | 4206.8 | 824.1 | 323.2 | 788.3 |
| Packaged shell stoker | 1 | .760 | 2.19 | 3582.7 | 735.8 | 350.4 | 628.9 |
| Packaged shell FBC | 1 | .760 | 1.84 | 4587.0 | 618.2 | 350.4 | 643.3 |
| Field erected stoker | 1 | .800 | 2.19 | 6497.4 | 699.0 | 348.3 | 619.2 |
| Field erected FBC | 1 | .800 | 1.84 | 7133.3 | 587.3 | 407.0 | 642.4 |
| Pulverized coal boiler | 1 | .820 | 1.84 | 7562.3 | 573.0 | 411.2 | 669.7 |
| Circulating FBC | 1 | .810 | 1.84 | 8473.6 | 580.1 | 348.3 | 701.4 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|---------------|------------------|--|---------------------|------------------------------------|--|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO | PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 0 | -- | | | |
| #2 Oil fired boiler | -- | -- | 0 | -- | | | |
| #6 Oil fired boiler | -- | -- | 23,091 | 1,000 | <--- Existing system, primary fuel | | |
| Micronized coal refit | 1 | 12,468 | 16,099 | 1.434 | 7.3 | 17,829 | 1.295 |
| Slagging burner refit | 1 | 12,468 | 17,660 | 1.308 | 11.2 | 20,352 | 1.135 |
| Modular FBC refit | 1 | 12,626 | 17,972 | 1.285 | 12.2 | 20,999 | 1.100 |
| Stoker firing refit | 1 | 12,923 | 17,445 | 1.324 | 9.4 | 19,433 | 1.188 |
| Coal/water slurry | 1 | 13,300 | 18,989 | 1.216 | 11.6 | 20,672 | 1.117 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | 1 | 14,473 | 20,207 | 1.143 | 16.9 | 22,827 | 1.012 |
| Packaged shell stoker | 1 | 12,923 | 17,868 | 1.292 | 10.7 | 20,118 | 1.148 |
| Packaged shell FBC | 1 | 13,125 | 17,712 | 1.304 | 11.3 | 20,446 | 1.129 |
| Field erected stoker | 1 | 12,277 | 19,839 | 1.164 | 17.1 | 23,563 | .980 |
| Field erected FBC | 1 | 12,468 | 20,026 | 1.153 | 18.0 | 24,065 | .960 |
| Pulverized coal boiler | 1 | 12,164 | 20,497 | 1.127 | 19.5 | 24,758 | .933 |
| Circulating FBC | 1 | 12,315 | 21,001 | 1.100 | 21.5 | 25,719 | .898 |

1:14 PM Oct 19, 1988

DOVER AFB: 1 X 50 MBtu/hr. FUEL, REAL ESCALATION ~ AEC 1987

Total steam output = 50.0 MBtu/hr
 Boiler capacity factor = .583
 Number of units for refit = 1
 Hydrated lime price (\$/ton) = 40.00
 Ash disposal price (\$/ton) = 10.00
 Electric price (cents/kWh) = 6.80
 Labor rate (k\$/yr) = 35.00
 Limestone price (\$/ton) = 20.00

FUEL PRICES
 Natural gas price (\$/MBtu) = .00
 #2 Oil price (\$/MBtu) = .00
 #6 Oil price (\$/MBtu) = 3.67

COAL PROPERTIES
 R.O.M. Stoker
 Ash fraction = .130 .100
 Sulfur fraction = .020 .020
 HHV (Btu/lb) = 12800. 13000.

FUEL PRICES
 R.O.M. coal (\$/MBtu) = 1.84
 Stoker coal (\$/MBtu) = 2.19
 Coal/H₂O mix (\$/MBtu) = 3.00
 Coal/oil mix (\$/MBtu) = 3.50

OPTIONS
 Soot blower multiplier = .0
 Tube bank mod multiplier = .0
 Bottom ash pit multiplier = 1.0
 SO₂ control multiplier = .0

LIMESTONE/LIME
 Inert fraction = .05

Primary fuel is 1
 #6 FUEL OIL
 1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988
 Gen infla index (1987 to base yr) = 1.040
 Gas infla index (1988 to base yr) = 1.000
 Oil infla index (1988 to base yr) = 1.000
 Coal infla index (1988 to base yr) = 1.000
 Project start year = 1990
 Project life (yr) = 30
 Depreciation life (yr) = 15
 General inflation rate (X/yr) = 0
 Type of gas escalation = egas
 Type of oil escalation = eoil
 Type of coal escalation = ecoal
 Discount rate (X/yr) = 10
 Rate of return on invest (X/yr) = 17
 Amount of working capital (month) = 2
 Federal income tax rate (X) = 34
 Local prop tax (& insur) rate (X) = 2

| | | REAL ESCALATION RATE (X/yr) | | | |
|------|----------------------------|-----------------------------|-------|-------|----------|
| FUEL | TYPE OF FUEL ESCALATION | 1988 | 1990 | 1995 | 2000 AND |
| | | -1990 | -1995 | -2000 | BEYOND |
| Gas | egas | 2.28 | 4.70 | 5.49 | 2.75 |
| Oil | eoil | .17 | 4.16 | 5.55 | 2.77 |
| Coal | ecoal | 1.46 | 1.76 | 1.61 | .81 |

1:22 PM Oct 19, 1988

POWER AFB: 1 X 50 Mbtu/hr. FUEL REAL ESCALATION = AEO 1987

Total steam output = 50.0 Mbtu/hr

Cost base year = 1988

Boiler capacity factor = .583

Primary fuel = #6 FUEL OIL

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/Mbtu | TOTAL CAPITAL \$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|------------------|--------------|----------------|----------------|
| | | | | | FUEL \$ | MAINT O & M \$ | OTHER O & M \$ |
| | | | | | \$ | \$ | \$ |
| Natural gas boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #2 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #6 Oil fired boiler | -- | .800 | 3.67 | .0 | 1171.4 | 165.4 | 484.6 |
| Micronized coal refit | 1 | .800 | 1.84 | 2616.3 | 587.3 | 368.2 | 662.0 |
| Slagging burner refit | 1 | .800 | 1.84 | 4504.8 | 587.3 | 368.2 | 662.0 |
| Modular FBC refit | 1 | .790 | 1.84 | 5173.9 | 594.7 | 350.4 | 642.6 |
| Stoker firing refit | 1 | .760 | 2.19 | 3070.2 | 735.8 | 350.4 | 628.9 |
| Coal/water slurry | 1 | .750 | 3.00 | 2353.1 | 1021.4 | 350.4 | 560.6 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2081.4 | 1145.6 | 279.0 | 532.2 |
| Low Btu gasifier refit | 1 | .679 | 2.19 | 4206.8 | 824.1 | 323.2 | 788.3 |
| Packaged shell stoker | 1 | .760 | 2.19 | 3582.7 | 735.8 | 350.4 | 628.9 |
| Packaged shell FBC | 1 | .760 | 1.84 | 4587.0 | 618.2 | 350.4 | 643.3 |
| Field erected stoker | 1 | .800 | 2.19 | 6497.4 | 699.0 | 348.3 | 619.2 |
| Field erected FBC | 1 | .800 | 1.84 | 7133.3 | 587.3 | 407.0 | 642.4 |
| Pulverized coal boiler | 1 | .820 | 1.84 | 7562.3 | 573.0 | 411.2 | 669.7 |
| Circulating FBC | 1 | .810 | 1.84 | 8473.6 | 580.1 | 348.3 | 701.4 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|---------------|------------------|-------------------|--------------------------------|------------------------------------|------------------|--------------------------------|
| | | | LIFE CYCLE COST, | DISCOUNTED BENEFIT/ COST RATIO | DISCOUNTED PAYBACK PERIOD, yr | LIFE CYCLE COST, | DISCOUNTED BENEFIT/ COST RATIO |
| | | | AS SPENT \$ | | | AS SPENT \$ | |
| Natural gas boiler | -- | -- | 0 | -- | | | |
| #2 Oil fired boiler | -- | -- | 0 | -- | | | |
| #6 Oil fired boiler | -- | -- | 19,019 | 1.000 | <--- Existing system, primary fuel | | |
| Micronized coal refit | 1 | 12,468 | 16,006 | 1.188 | 11.8 | 17,733 | 1.073 |
| Slagging burner refit | 1 | 12,468 | 17,567 | 1.083 | 19.4 | 20,256 | .939 |
| Modular FBC refit | 1 | 12,626 | 17,878 | 1.064 | 21.5 | 20,902 | .910 |
| Stoker firing refit | 1 | 12,923 | 17,328 | 1.098 | 17.1 | 19,313 | .985 |
| Coal/water slurry | 1 | 13,300 | 18,826 | 1.010 | 28.2 | 20,505 | .928 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | 1 | 14,473 | 20,076 | .947 | >31 | 22,692 | .838 |
| Packaged shell stoker | 1 | 12,923 | 17,751 | 1.071 | 19.7 | 19,998 | .951 |
| Packaged shell FBC | 1 | 13,125 | 17,614 | 1.080 | 19.7 | 20,345 | .935 |
| Field erected stoker | 1 | 12,277 | 19,728 | .964 | >31 | 23,449 | .811 |
| Field erected FBC | 1 | 12,468 | 19,933 | .954 | >31 | 23,969 | .793 |
| Pulverized coal boiler | 1 | 12,164 | 20,406 | .932 | >31 | 24,364 | .771 |
| Circulating FBC | 1 | 12,315 | 20,909 | .910 | >31 | 25,624 | .742 |

DOVER AFB: 1 X 30 MBtu/hr. FUEL REAL ESCALATION = ZERO

Total steam output = 50.0 MBtu/hr

Boiler capacity factor = .583

Number of units for refit = 1

Hydrated lime price (\$/ton) = 40.00

Ash disposal price (\$/ton) = 10.00

Electric price (cents/kWh) = 6.80

Labor rate (k\$/yr) = 35.00

Limestone price (\$/ton) = 20.00

FUEL PRICES

Natural gas price (\$/MBtu) = .00

#2 Oil price (\$/MBtu) = .00

#6 Oil price (\$/MBtu) = 3.67

OPTIONS

Soot blower multiplier = .0

Tube bank mod multiplier = .0

Bottom ash pit multiplier = 1.0

SO2 control multiplier = .0

LIMESTONE/LIME

Inert fraction = .05

COAL PROPERTIES**R.O.M. Stoker**

Ash fraction = .130 .190

Sulfur fraction = .020 .020

HHV (Btu/lb) = 12800. 13000.

FUEL PRICES

R.O.M. coal (\$/MBtu) = 1.84

Stoker coal (\$/MBtu) = 2.19

Coal/H2O mix (\$/MBtu) = 3.00

Coal/oil mix (\$/MBtu) = 3.50

Primary fuel is 1

#6 FUEL OIL

1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988

Gen infla index (1987 to base yr) = 1.040

Gas infla index (1988 to base yr) = 1.000

Oil infla index (1988 to base yr) = 1.000

Coal infla index (1988 to base yr) = 1.000

Project start year = 1990

Project life (yr) = 30

Depreciation life (yr) = 15

General inflation rate (X/yr) = 0

Type of gas escalation = zero

Type of oil escalation = zero

Type of coal escalation = zero

Discount rate (X/yr) = 10

Rate of return on invest (X/yr) = 17

Amount of working capital (month) = 2

Federal income tax rate (X) = 34

Local prop tax (& insur) rate (X) = 2

| FUEL | TYPE OF FUEL ESCALATION | REAL ESCALATION RATE (X/yr) | | | |
|------|----------------------------|-----------------------------|---------------|---------------|--------------------|
| | | 1988 -1990 | 1990 -1995 | 1995 -2000 | 2000 AND BEYOND |
| Gas | zero | 0 | 0 | 0 | 0 |
| Oil | zero | 0 | 0 | 0 | 0 |
| Coal | zero | 0 | 0 | 0 | 0 |

1:29 PM Oct 19, 1988

DOVER AFB: 1 X 50 MBtu/hr. FUEL REAL ESCALATION = ZERO

Total steam output = 50.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .583

Primary fuel = #6 FUEL OIL

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & H k\$ | OTHER O & H k\$ |
| Natural gas boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #2 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #6 Oil fired boiler | -- | .800 | 3.67 | .0 | 1171.4 | 165.4 | 484.6 |
| Micronized coal refit | 1 | .800 | 1.84 | 2616.3 | 587.3 | 368.2 | 662.0 |
| Slagging burner refit | 1 | .800 | 1.84 | 4504.8 | 587.3 | 368.2 | 662.0 |
| Modular FBC refit | 1 | .790 | 1.84 | 5173.9 | 594.7 | 350.4 | 642.6 |
| Stoker firing refit | 1 | .760 | 2.19 | 3070.2 | 735.8 | 350.4 | 628.9 |
| Coal/water slurry | 1 | .750 | 3.00 | 2353.1 | 1021.4 | 350.4 | 560.6 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2081.4 | 1145.8 | 279.0 | 532.2 |
| Low Btu gasifier refit | 1 | .679 | 2.19 | 4206.8 | 824.1 | 323.2 | 788.3 |
| Packaged shell stoker | 1 | .760 | 2.19 | 3582.7 | 735.8 | 350.4 | 628.9 |
| Packaged shell FBC | 1 | .760 | 1.84 | 4587.0 | 618.2 | 350.4 | 643.3 |
| Field erected stoker | 1 | .800 | 2.19 | 6497.4 | 699.0 | 348.3 | 619.2 |
| Field erected FBC | 1 | .800 | 1.84 | 7133.3 | 587.3 | 407.0 | 642.4 |
| Pulverized coal boiler | 1 | .820 | 1.84 | 7562.3 | 573.0 | 411.2 | 669.7 |
| Circulating FBC | 1 | .810 | 1.84 | 8473.6 | 580.1 | 348.3 | 701.4 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|---------------|------------------|--|---------------------|------------------------------------|--|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO | PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 0 | -- | | | |
| #2 Oil fired boiler | -- | -- | 0 | -- | | | |
| #6 Oil fired boiler | -- | -- | 14,381 | 1.000 | <--- Existing system, primary fuel | | |
| Micronized coal refit | 1 | 12,468 | 15,188 | .947 | >31 | 16,891 | .851 |
| Slagging burner refit | 1 | 12,468 | 16,749 | .859 | >31 | 19,415 | .741 |
| Modular FBC refit | 1 | 12,626 | 17,050 | .843 | >31 | 20,050 | .717 |
| Stoker firing refit | 1 | 12,923 | 16,303 | .882 | >31 | 18,259 | .788 |
| Coal/water slurry | 1 | 13,300 | 17,404 | .826 | >31 | 19,042 | .755 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | 1 | 14,473 | 18,929 | .760 | >31 | 21,512 | .665 |
| Packaged shell stoker | 1 | 12,923 | 16,727 | .860 | >31 | 18,944 | .759 |
| Packaged shell FBC | 1 | 13,125 | 16,753 | .858 | >31 | 19,459 | .739 |
| Field erected stoker | 1 | 12,277 | 18,754 | .767 | >31 | 22,447 | .641 |
| Field erected FBC | 1 | 12,468 | 19,115 | .752 | >31 | 23,128 | .622 |
| Pulverized coal boiler | 1 | 12,164 | 19,608 | .733 | >31 | 23,844 | .603 |
| Circulating FBC | 1 | 12,315 | 20,101 | .715 | >31 | 24,794 | .580 |

1:29 PM Oct 19, 1988

McGUIRE AFB: MAC

1. BACKGROUND

McGuire AFB is located near Trenton, New Jersey. The main boiler plant at McGuire used coal until 1970 when all boilers were switched to natural gas and distillate oil (backup fuel). All boilers are water-tube, high-temperature, hot-water units and have Cleaver Brooks electrostatic precipitators. Boiler efficiencies are reported as 74-70%. Fuel use is about 500,000 MBtu/year, for a yearly average of -57 MBtu/h. Earlier data indicate that fuel use was previously much higher. Probably no coal-handling equipment is repairable.

2. HEATING PLANT UNITS

Heating Plant No. 2101:

4 x 50 MBtu/h, Combustion Engineering, 1953
2 x 31.2 MBtu/h, Erie City, 1960

3. IDEAL CAPACITY FACTOR ANALYSIS

The ideal capacity factors listed below were calculated from monthly fuel-use data for plant No. 2101.

| Fuel input (MBtu/h) | CY 1985 ideal capacity factor | FY 1986 ideal capacity factor |
|---------------------------|--|--|
| 30 | 0.93 | 0.92 |
| 40 | 0.82 | 0.82 |
| 50 | 0.76 | 0.76 |
| 60 | 0.71 | 0.71 |
| 70 | 0.67 | 0.66 |
| 80 | 0.63 | 0.62 |

4. ENERGY PRICES

FY 1986 Price Data:

| | Average | Year end |
|-------------|-------------|-------------|
| Electricity | 7.0¢/kWh | Same |
| Distillate | \$6.85/MBtu | Same |
| Natural gas | \$3.85/MBtu | \$2.70/MBtu |

C. H. Guernsey and Co. Survey:

Electricity = 7.8¢/kWh
Distillate = \$5.56/MBtu
Natural gas = \$5.40/MBtu (this is apparently a mistake)

An inquiry into the gas price revealed that the price fluctuates and the gas supply is interruptible. The gas supply is only rarely interrupted, and a cost of about \$4.00/MBtu would be representative.

5. COAL PROPERTIES AND PRICES

| | Stoker | ROM |
|-------------------------------------|---------------------|---------------------|
| Origin | Clearfield Co., Pa. | Clearfield Co., Pa. |
| HHV, Btu/lb | 13,000 | 12,800 |
| % Ash | 10 | 13 |
| % Sulfur | 2 | 2 |
| % Nitrogen | 1.5 | 1.5 |
| Ash-softening temperature, °F | 2450 | 2450 |
| Swelling index | 8-9 | 8-9 |
| Top size, in. | 1 1/4 | 2 |
| Bottom size, in. | 3/8 | 0 |
| Fines, % | 15 | |
| Grindability index | 90+ | 90+ |
| Cost at mine, \$/ton | 40 | 30 |
| Delivered cost, \$/ton | 58.50 | 48.50 |
| Energy cost, \$/10 ⁶ Btu | 2.25 | 1.89 |

6. ENVIRONMENTAL REGULATIONS

6.1 Air Pollution Emission Limits for New Sources

SO₂. For boilers >250 MBtu/h: 0.6 lb/MBtu and 70% reduction;
For boilers >1 and <250 MBtu/h: 0.3 lb/MBtu.

NO_x. No emission limits for boilers <100 MBtu/h; for boilers >100 MBtu/h: spreader stoker and FBC - 0.6 lb/MBtu; pulverized coal - 0.7 lb/MBtu.

Particulates. 0.03 lb/MBtu (state-of-the-art technology required).

6.2 Coal-Pile Runoff

Limit: Total suspended solids - 50 mg/L.

6.3 Ash Disposal

Ashes are classified as nonhazardous solid waste and may be disposed of in any approved sanitary landfill.

7. OTHER CONSIDERATIONS

Electric use in FY 1986 was 55,000 MWh, an average of 6.3 MW.

8. COAL-CONVERSION PROJECT OUTLOOK

A conversion project using coal to generate 50 MBtu/h of steam (~65 MBtu/h fuel input) may be feasible. Assuming 90% equipment availability, an overall capacity factor of about 62% could be expected. The price of natural gas is very important to the economics of such a project; the discrepancy in price must be investigated further.

8.1 Effect of Environmental Regulations on Selection of Combustion Technologies

SO₂. The strict SO₂ emission limit will require 90% or greater SO₂ reduction while burning 2% sulfur coal, which will necessitate the use of a flue gas scrubber with stoker firing, limestone addition with micronized coal or FBC, or the use of deep-cleaned coal-water-mixture fuel.

NO_x. No special measures will be required for NO_x reduction because the proposed conversion project is smaller than 100 MBtu/h.

Particulates. Bag filters or electrostatic precipitators will be required to comply with the strict particulate emission limits except for the case of using a wet scrubber for SO₂ control. Electrostatic precipitators are still in place and may be reusable.

8.2 Physical Space and Aesthetics

Heating Plant. The existing boiler plant was originally designed for coal. There is space available for reinstalling coal-combustion equipment at the existing boiler or for construction of a new boiler at another site on base.

Coal-Handling Equipment. Most of the auxiliary equipment is still in place, but some of it is in very bad condition and cannot be used.

Coal Pile. There is space available for a coal pile at the existing boiler plant or at a new site on base.

8.3 Technical Risk of Combustion Technologies

Because of the need for strict SO₂ control, the technical risk is about equal for all the coal-combustion technologies. Refit of stoker firing would be the lowest risk for the combustion process, but the need for a flue gas scrubber increases the overall risk for that option.

9. COGENERATION PROJECT OUTLOOK

The prospects appear to be potentially favorable for a coal-fired cogeneration system. The minimum monthly average electric load is about 5.2 MWe and the price of electricity is high (7.8¢/kWh). Based on the FY 1986 energy-use data, a cogeneration plant with a boiler rating of 68 MBtu/h output and a 5-MWe turbine-generator would have an electrical power capacity factor of about 90% and a peak thermal output of 50 MBtu/h with a thermal energy capacity factor of about 72% if used as a baseload heating plant. A water-tube boiler with a steam rating of 1450 psia and 950°F would be the most suitable type of boiler for such a cogeneration plant.

10. INPUT AND LCC SUMMARY SPREADSHEETS

MCQUIRE AFB: 1 X 50 MBtu/hr. ECONOMIC PARAMETERS = NOMINAL VALUES

Total steam output = 50.0 MBtu/hr
 Boiler capacity factor = .618
 Number of units for refit = 1
 Hydrated lime price (\$/ton) = 40.00
 Ash disposal price (\$/ton) = 10.00
 Electric price (cents/kWh) = 7.80
 Labor rate (k\$/yr) = 35.00
 Limestone price (\$/ton) = 20.00
 FUEL PRICES
 Natural gas price (\$/MBtu) = 4.00
 #2 Oil price (\$/MBtu) = 4.71
 #6 Oil price (\$/MBtu) = .00
 OPTIONS
 Soot blower multiplier = .0
 Tube bank mod multiplier = .0
 Bottom ash pit multiplier = 1.0
 SO2 control multiplier = 1.0
 LIMESTONE/LIME
 Inert fraction = .05

COAL PROPERTIES
 R.O.M. Stoker
 Ash fraction = .130 .100
 Sulfur fraction = .020 .020
 HHV (Btu/lb) = 12800. 13000.
 FUEL PRICES
 R.O.M. coal (\$/MBtu) = 1.89
 Stoker coal (\$/MBtu) = 2.25
 Coal/H2O mix (\$/MBtu) = 3.00
 Coal/oil mix (\$/MBtu) = 3.50
 Primary fuel is 3
 NATURAL GAS
 1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988
 Gen infla index (1987 to base yr) = 1.040
 Gas infla index (1988 to base yr) = 1.000
 Oil infla index (1988 to base yr) = 1.000
 Coal infla index (1988 to base yr) = 1.000
 Project start year = 1990
 Project life (yr) = 30
 Depreciation life (yr) = 15
 General inflation rate (I/yr) = 0
 Type of gas escalation = egas
 Type of oil escalation = eoil
 Type of coal escalation = ecoal
 Discount rate (I/yr) = 10
 Rate of return on invest (I/yr) = 17
 Amount of working capital (month) = 2
 Federal income tax rate (T) = 34
 Local prop tax (& insur) rate (T) = 2

| | | REAL ESCALATION RATE (I/yr) | | | |
|------|--------------|-----------------------------|-------|-------|----------|
| FUEL | TYPE OF FUEL | 1988 | 1990 | 1995 | 2000 AND |
| | ESCALATION | -1990 | -1995 | -2000 | BEYOND |
| Gas | egas | 3.89 | 8.87 | 5.77 | 5.77 |
| Oil | eoil | 4.66 | 7.87 | 4.16 | 4.16 |
| Coal | ecoal | 1.16 | 2.31 | 1.19 | 1.19 |

11:34 AM Oct 20, 1988

MCQUIRE AFB: 1 X 50 MBtu/hr. ECONOMIC PARAMETERS - NOMINAL VALUES

Total steam output = 50.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .616

Primary fuel = NATURAL GAS

Number of units for: refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | OTHER O & M k\$ |
| Natural gas boiler | -- | .800 | 4.00 | .0 | 1243.4 | 165.4 | 496.2 |
| #2 Oil fired boiler | -- | .800 | 4.71 | .0 | 1593.7 | 165.4 | 496.2 |
| #6 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| Micronized coal refit | 1 | .800 | 1.89 | 2907.2 | 639.5 | 368.2 | 776.5 |
| Slagging burner refit | 1 | .800 | 1.89 | 4795.6 | 639.5 | 368.2 | 776.5 |
| Modular FBC refit | 1 | .790 | 1.89 | 5442.3 | 647.6 | 350.4 | 741.0 |
| Stoker firing refit | 1 | .740 | 2.25 | 4454.4 | 823.0 | 541.9 | 740.4 |
| Coal/water slurry | 1 | .750 | 3.00 | 2651.5 | 1082.7 | 350.4 | 673.7 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2294.9 | 1214.6 | 279.0 | 590.0 |
| Low Btu gasifier refit | 1 | .659 | 2.25 | 5034.9 | 924.7 | 323.2 | 1006.5 |
| Packaged shell stoker | 1 | .740 | 2.25 | 4966.9 | 823.0 | 541.9 | 740.4 |
| Packaged shell FBC | 1 | .760 | 1.89 | 4859.5 | 673.1 | 350.4 | 744.8 |
| Field erected stoker | 1 | .780 | 2.2 | 7877.2 | 780.8 | 539.8 | 726.0 |
| Field erected FBC | 1 | .800 | 1.89 | 7216.3 | 639.5 | 407.0 | 739.8 |
| Pulverized coal boiler | 1 | .800 | 1.89 | 6942.1 | 639.5 | 602.7 | 779.0 |
| Circulating FBC | 1 | .810 | 1.89 | 8543.9 | 631.6 | 348.3 | 779.9 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|---------------|------------------|--|---------------------|------------------------------------|--|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO | DISCOUNTED PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 29,110 | 1.000 | <--- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 29,610 | -- | | | |
| #6 Oil fired boiler | -- | -- | 0 | -- | | | |
| Micronized coal refit | 1 | 13,217 | 17,719 | 1.643 | 6.8 | 19,636 | 1.482 |
| Slagging burner refit | 1 | 13,217 | 19,280 | 1.510 | 9.7 | 22,160 | 1.314 |
| Modular FBC refit | 1 | 13,384 | 19,454 | 1.496 | 10.3 | 22,654 | 1.285 |
| Stoker firing refit | 1 | 14,069 | 21,984 | 1.324 | 13.1 | 24,774 | 1.175 |
| Coal/water slurry | 1 | 14,098 | 20,689 | 1.407 | 6 | 22,566 | 1.260 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | 1 | 15,808 | 23,547 | 1.236 | 16.2 | 26,085 | 1.082 |
| Packaged shell stoker | 1 | 14,039 | 22,407 | 1.299 | 14.1 | 25,459 | 1.143 |
| Packaged shell FBC | 1 | 13,913 | 19,241 | 1.513 | 9.7 | 22,151 | 1.314 |
| Field erected stoker | 1 | 13,347 | 24,288 | 1.199 | 18.6 | 28,809 | 1.010 |
| Field erected FBC | 1 | 13,217 | 21,341 | 1.364 | 13.5 | 25,457 | 1.143 |
| Pulverized coal boiler | 1 | 13,217 | 24,823 | 1.173 | 19.9 | 29,877 | .974 |
| Circulating FBC | 1 | 13,054 | 22,152 | 1.314 | 15.2 | 26,938 | 1.081 |

11:34 AM Oct 20, 1988

MCQUIRE AFB: 1 X 50 MBtu/hr. FUEL REAL ESCALATION - AEO 1987

Total steam output = 50.0 MBtu/hr

Boiler capacity factor = .818

Number of units for refit = 1

Hydrated lime price (\$/ton) = 40.00

Ash disposal price (\$/ton) = 10.00

Electric price (cents/kWh) = 7.80

Labor rate (\$/yr) = 35.00

Limestone price (\$/ton) = 20.00

FUEL PRICES

Natural gas price (\$/MBtu) = 4.00

#2 Oil price (\$/MBtu) = 4.71

#6 Oil price (\$/MBtu) = .00

OPTIONS

Soot blower multiplier = .0

Tube bank mod multiplier = .0

Bottom ash pit multiplier = 1.0

SO2 control multiplier = 1.0

LIMESTONE/LIME

Inert fraction = .05

COAL PROPERTIESR.O.M. Stoker

Ash fraction = .130 .100

Sulfur fraction = .020 .020

HHV (Btu/lb) = 12800. 13000.

FUEL PRICES

R.O.M. coal (\$/MBtu) = 1.89

Stoker coal (\$/MBtu) = 2.25

Coal/H2O mix (\$/MBtu) = 3.00

Coal/oil mix (\$/MBtu) = 3.50

Primary fuel is 3

NATURAL GAS

1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988

Gen infla index (1987 to base yr) = 1.040

Gas infla index (1988 to base yr) = 1.000

Oil infla index (1988 to base yr) = 1.000

Coal infla index (1988 to base yr) = 1.000

Project start year = 1990

Project life (yr) = 30

Depreciation life (yr) = 15

General inflation rate (I/yr) = 0

Type of gas escalation = egas

Type of oil escalation = eoil

Type of coal escalation = ecoal

Discount rate (I/yr) = 10

Rate of return on invest (I/yr) = 17

Amount of working capital (month) = 2

Federal income tax rate (I) = 34

Local prop tax (& insur) rate (I) = 2

REAL ESCALATION RATE (I/yr)

| FUEL | TYPE OF FUEL ESCALATION | 1988 | 1990 | 1995 | 2000 AND |
|------|----------------------------|-------|-------|-------|----------|
| | | -1990 | -1995 | -2000 | BEYOND |
| Gas | egas | 2.28 | 4.70 | 5.49 | 2.75 |
| Oil | eoil | .17 | 4.16 | 5.55 | 2.77 |
| Coal | ecoal | 1.46 | 1.78 | 1.61 | .81 |

11:40 AM Oct 20, 1988

MCQUIRE AFB: 1 X 50 MBtu/hr. FUEL REAL ESCALATION - AEO 1987

Total steam output = 50.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .618

Primary fuel = NATURAL GAS

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | OTHER O & M k\$ |
| Natural gas boiler | -- | .800 | 4.00 | .0 | 1353.4 | 165.4 | 498.2 |
| #2 Oil fired boiler | -- | .800 | 4.71 | .0 | 1593.7 | 165.4 | 498.2 |
| #6 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| Micronized coal refit | 1 | .800 | 1.89 | 2007.2 | 639.5 | 368.2 | 776.5 |
| Slagging burner refit | 1 | .800 | 1.89 | 4795.8 | 639.5 | 368.2 | 776.5 |
| Modular FBC refit | 1 | .790 | 1.89 | 5442.3 | 647.6 | 350.4 | 741.0 |
| Stoker firing refit | 1 | .740 | 2.25 | 4454.4 | 823.0 | 541.9 | 740.4 |
| Coal/water slurry | 1 | .750 | 3.00 | 2651.5 | 1082.7 | 350.4 | 673.7 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2294.9 | 1214.6 | 279.0 | 590.0 |
| Low Btu gasifier refit | 1 | .659 | 2.25 | 5034.9 | 924.7 | 323.2 | 1008.5 |
| Packaged shell stoker | 1 | .740 | 2.25 | 4966.9 | 823.0 | 541.9 | 740.4 |
| Packaged shell FBC | 1 | .760 | 1.89 | 4859.5 | 673.1 | 350.4 | 744.8 |
| Field erected stoker | 1 | .780 | 2.25 | 7877.2 | 780.8 | 539.8 | 726.0 |
| Field erected FBC | 1 | .800 | 1.89 | 7216.3 | 639.5 | 407.0 | 739.8 |
| Pulverized coal boiler | 1 | .800 | 1.89 | 8942.1 | 639.5 | 602.7 | 779.0 |
| Circulating FBC | 1 | .810 | 1.89 | 8543.9 | 631.6 | 348.3 | 779.9 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|---------------|------------------|--|---------------------|------------------------------------|--|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO | DISCOUNTED PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 22,261 | 1.000 | <--- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 24,070 | -- | | | |
| #6 Oil fired boiler | -- | -- | 0 | -- | | | |
| Micronized coal refit | 1 | 13,217 | 17,618 | 1.264 | 9.7 | 19,531 | 1.140 |
| Slagging burner refit | 1 | 13,217 | 19,178 | 1.151 | 14.7 | 22,055 | 1.009 |
| Modular FBC refit | 1 | 13,384 | 19,351 | 1.150 | 15.6 | 22,548 | .987 |
| Stoker firing refit | 1 | 14,069 | 21,853 | 1.019 | 26.8 | 24,640 | .903 |
| Coal/water slurry | 1 | 14,098 | 20,517 | 1.085 | 17.6 | 22,388 | .994 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | 1 | 15,808 | 23,400 | .951 | >31 | 26,513 | .840 |
| Packaged shell stoker | 1 | 14,069 | 22,277 | .989 | >31 | 25,325 | .879 |
| Packaged shell FBC | 1 | 13,913 | 19,134 | 1.163 | 14.6 | 22,041 | 1.010 |
| Field erected stoker | 1 | 13,347 | 24,164 | .921 | >31 | 28,681 | .776 |
| Field erected FBC | 1 | 13,217 | 21,239 | 1.048 | 23.7 | 25,353 | .878 |
| Pulverized coal boiler | 1 | 13,217 | 24,721 | .901 | >31 | 29,773 | .748 |
| Circulating FBC | 1 | 13,054 | 22,052 | 1.009 | 29.2 | 26,834 | .830 |

11:40 AM Oct 20, 1988

MCQUIRE AFB: 1 X 50 MBtu/hr. FUEL REAL ESCALATION = ZERO

Total steam output = 50.0 MBtu/hr
 Boiler capacity factor = .618
 Number of units for refit = 1
 Hydrated lime price (\$/ton) = 40.00
 Ash disposal price (\$/ton) = 10.00
 Electric price (cents/kWh) = 7.80
 Labor rate (k\$/yr) = 35.00
 Limestone price (\$/ton) = 20.00

FUEL PRICES
 Natural gas price (\$/MBtu) = 4.00
 #2 Oil price (\$/MBtu) = 4.71
 #6 Oil price (\$/MBtu) = .00

COAL PROPERTIES
 R.O.M. Stoker
 Ash fraction = .130 .100
 Sulfur fraction = .020 .020
 HHV (Btu/lb) = 12800. 13000.

FUEL PRICES
 R.O.M. coal (\$/MBtu) = 1.89
 Stoker coal (\$/MBtu) = 2.25
 Coal/H₂O mix (\$/MBtu) = 3.00
 Coal/oil mix (\$/MBtu) = 3.50

OPTIONS
 Soot blower multiplier = .0
 Tube bank mod multiplier = .0
 Bottom ash pit multiplier = 1.0
 SO₂ control multiplier = 1.0

LIMESTONE/LIME
 Inert fraction = .05

Primary fuel is 3
 NATURAL GAS
 1-#6 Oil, 2-#2 Oil, 3=NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988
 Gen infla index (1987 to base yr) = 1.040
 Gas infla index (1988 to base yr) = 1.000
 Oil infla index (1988 to base yr) = 1.000
 Coal infla index (1988 to base yr) = 1.000
 Project start year = 1990
 Project life (yr) = 30
 Depreciation life (yr) = 15
 General inflation rate (I/yr) = 0
 Type of gas escalation = zero
 Type of oil escalation = zero
 Type of coal escalation = zero
 Discount rate (I/yr) = 10
 Rate of return on invest (I/yr) = 17
 Amount of working capital (month) = 2
 Federal income tax rate (I) = 34
 Local prop tax (& insur) rate (I) = 2

| | | REAL ESCALATION RATE (I/yr) | | | |
|------|----------------------------|-----------------------------|-------|-------|----------|
| FUEL | TYPE OF FUEL ESCALATION | 1988 | 1990 | 1995 | 2000 AND |
| | | -1990 | -1995 | -2000 | BEYOND |
| Gas | zero | 0 | 0 | 0 | 0 |
| Oil | zero | 0 | 0 | 0 | 0 |
| Coal | zero | 0 | 0 | 0 | 0 |

11:47 AM Oct 20, 1988

MCQUIRE AFB: 1 X 30 MBtu/hr. FUEL REAL ESCALATION = ZERO

Total steam output = 30.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .618

Primary fuel = NATURAL GAS

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | OTHER O & M k\$ |
| Natural gas boiler | -- | .800 | 4.00 | .0 | 1353.4 | 165.4 | 496.2 |
| #2 Oil fired boiler | -- | .800 | 4.71 | .0 | 1593.7 | 165.4 | 496.2 |
| #6 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| Micronized coal refit | 1 | .800 | 1.89 | 2907.2 | 639.5 | 368.2 | 776.5 |
| Slagging burner refit | 1 | .800 | 1.89 | 4795.6 | 639.5 | 368.2 | 776.5 |
| Modular FBC refit | 1 | .790 | 1.89 | 5442.3 | 647.6 | 350.4 | 741.0 |
| Stoker firing refit | 1 | .740 | 2.25 | 4454.4 | 823.0 | 541.9 | 740.4 |
| Coal/water slurry | 1 | .750 | 3.00 | 2651.5 | 1082.7 | 350.4 | 673.7 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2294.9 | 1214.6 | 279.0 | 590.0 |
| Low Btu gasifier refit | 1 | .659 | 2.25 | 5034.9 | 924.7 | 323.2 | 1008.5 |
| Packaged shell stoker | 1 | .740 | 2.25 | 4986.9 | 823.0 | 541.9 | 740.4 |
| Packaged shell FBC | 1 | .760 | 1.89 | 4859.5 | 673.1 | 350.4 | 744.8 |
| Field erected stoker | 1 | .780 | 2.25 | 7877.2 | 780.8 | 539.8 | 726.0 |
| Field erected FBC | 1 | .800 | 1.89 | 7216.3 | 639.5 | 407.0 | 739.8 |
| Pulverized coal boiler | 1 | .800 | 1.89 | 8942.1 | 639.5 | 802.7 | 779.0 |
| Circulating FBC | 1 | .810 | 1.89 | 8543.9 | 631.6 | 348.3 | 779.9 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|---------------|------------------|--|---------------------|------------------------------------|--|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO | PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 15,889 | 1.000 | <--- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 17,761 | -- | | | |
| #6 Oil fired boiler | -- | -- | 0 | -- | | | |
| Micronized coal refit | 1 | 13,217 | 16,727 | .950 | >31 | 18,615 | .854 |
| Slagging burner refit | 1 | 13,217 | 18,288 | .869 | >31 | 21,139 | .752 |
| Modular FBC refit | 1 | 13,384 | 18,449 | .861 | >31 | 21,620 | .735 |
| Stoker firing refit | 1 | 14,069 | 20,707 | .767 | >31 | 23,461 | .677 |
| Coal/water slurry | 1 | 14,098 | 19,009 | .836 | >31 | 20,838 | .783 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | 1 | 15,808 | 22,112 | .719 | >31 | 25,189 | .631 |
| Packaged shell stoker | 1 | 14,069 | 21,130 | .752 | >31 | 24,146 | .658 |
| Packaged shell FBC | 1 | 13,913 | 18,197 | .873 | >31 | 21,077 | .754 |
| Field erected stoker | 1 | 13,347 | 23,076 | .689 | >31 | 27,563 | .576 |
| Field erected FBC | 1 | 13,217 | 20,349 | .781 | >31 | 24,437 | .650 |
| Pulverized coal boiler | 1 | 13,217 | 23,830 | .667 | >31 | 28,857 | .551 |
| Circulating FBC | 1 | 13,054 | 21,172 | .750 | >31 | 25,930 | .613 |

11:47 AM Oct 20, 1988

SCOTT AFB: MAC

1. BACKGROUND

Scott AFB is located near Belleville, Illinois. There are four steam plants on this base, but only the major one is of any interest. The capacity of this plant is about 250 MBtu/h (the others are about 20, 31, and 14 MBtu/h) and is composed of four Erie City Iron Works boilers. The boilers in the main steam plant burned coal previously but were converted to No. 6 oil. Currently, the main plant burns natural gas, and the yearly average fuel use is roughly 40 MBtu/h.

2. HEATING PLANT UNITS

Heating Plant No. 45:

83 MBtu/h, Erie City Iron Works, 1955

40 MBtu/h, Erie City Iron Works, 1952

84 and 45 MBtu/h, Erie City Iron Works, 1939

3. IDEAL CAPACITY FACTOR ANALYSIS

The maximum possible capacity factors listed below were calculated from monthly fuel-use data for plant No. 45.

| Fuel input (MBtu/h) | CY 1985 ideal capacity factor | FY 1986 ideal capacity factor |
|---------------------------|--|--|
| 30 | 0.90 | 0.87 |
| 40 | 0.79 | 0.77 |
| 50 | 0.70 | 0.69 |
| 60 | 0.63 | 0.63 |
| 70 | 0.56 | 0.57 |
| 80 | 0.50 | 0.52 |
| 90 | 0.44 | 0.46 |

4. ENERGY PRICES

FY 1986 Price Data:

| | Average | Year end |
|----------------|-------------|-------------|
| Electricity | 4.1¢/kWh | 4.9¢/kWh |
| Residual oil | \$5.28/MBtu | Same |
| Distillate oil | \$5.90/MBtu | Same |
| Natural gas | \$3.64/MBtu | \$3.80/MBtu |

5. COAL PROPERTIES AND PRICES

| | Stoker | Run of Mine |
|-------------------------------|------------------|------------------|
| Origin | Belleville, Ill. | Belleville, Ill. |
| HHV, Btu/lb | 10,888 | 10,309 |
| Ash, % | 10.70 | 11.18 |
| Sulfur, % | 3.74 | 3.70 |
| Nitrogen, % | | |
| Ash-softening temperature, °F | | |
| Swelling index | | |
| Top size, in. | 1 | 1.5 x 0 |
| Bottom size, in. | 28 mesh | |
| Fines, % | 9-12 | 25 |
| Grindability index | | |
| Cost at mine, \$/ton | 23.50 | 22.00 |
| Delivered cost, \$/ton | 27.50 | 26.00 |
| Energy cost, \$/MBtu | 1.26 | 1.24 |

6. ENVIRONMENTAL REGULATIONS

6.1 Air Pollution Emission Limits for New Sources

SO₂: The Illinois emission limit for sulfur dioxide is 1.8 lb/MBtu in any 1-h period.

NO_x: The State does not have limits on nitrogen oxide emissions for fuel-burning sources of this size (<250 MBtu/h).

Particulates. Scott AFB is located in a nonattainment area for particulates. The State of Illinois particulate limit applicable to a plant boiler converted to coal firing is 0.1 lb/MBtu actual heat input. Nonattainment regulations require the base to operate the boiler at the lowest achievable emission rate (LAER). The operator must demonstrate that the control equipment and process measures will produce the LAER. Emission offsets are also applicable; however, in cases where no practical offsets are found, certain exemptions may be obtainable.

The opacity limits for new fuel-combustion sources of this size (≤250 MBtu/hr) is ≤30% with the exception that the opacity may range between 30 and 60% for a period or periods aggregating 8 min in a 60-min period.

6.2 Coal-Pile Runoff

The State of Illinois requires that coal storage yards obtain a National Pollutant Discharge Elimination System (NPDES) permit if coal-pile runoff is discharged into waters of the State. During the permit application review, the State Agency determines if a facility will cause or threaten to cause water pollution by its location, geology, operation, and abandonment plan.

The State of Illinois utilizes EPA federal regulation for coal-pile runoff. The regulations state the the pH of all discharges, except once-through cooling water, shall be within the range of 6.0 to 9.0. The effluent limitation for the point source discharges of coal-pile runoff is 50 mg/L total suspended solids.

6.3 Ash Disposal

Coal ash is classified as a special waste by the State of Illinois and requires a special permit for handling. A permit for special waste handling must be obtained by existing disposal sites that accept the ash or, for new disposal sites, an operating permit must be issued.

7. OTHER CONSIDERATIONS

None

8. COAL-CONVERSION PROJECT OUTLOOK

A conversion project would probably involve conversion of one 40-Btu/h output (50-MBtu/h fuel input) boiler. A realistic overall capacity factor for a 40-MBtu/h coal-burning unit would be about 63%, assuming 90% availability.

8.1 Effect of Environmental Regulations on Selection of Combustion Technologies

SO₂. Sulfur dioxide removal will be required for all combustion technologies because of the high-sulfur (3.7%) coal.

NO_x. No special nitrogen oxide controls will be required for any of the combustion technologies.

Particulates. Bag filters or electrostatic precipitators will be required.

8.2 Physical Space and Aesthetics

Heating Plant. The existing boilers were originally designed for coal, but there is no information about availability of space for reinstalling coal-combustion equipment.

Coal-Handling Equipment. There is not enough room for installing dry coal-handling equipment at the existing site, but there is space for coal-water-mixture equipment.

Coal Pile. There is no space available for a coal pile at the existing plant, but there is space at another site on base for a coal pile and a new coal-fired boiler.

8.3 Technical Risk of Combustion Technologies

The existing boilers were designed for coal, but the technical risk of burning a coal-water mixture would be moderate because of the need for SO₂ removal. The least technical risk would be for a new stoker or FBC boiler.

9. COGENERATION PROJECT OUTLOOK

The prospects for coal-fired cogeneration systems appear to be poor because of the low cost of electricity (4.1¢/kWh in FY 1986; however, by the year's end, about 4.9¢/kWh). The monthly minimum average electric demand was 2453 MWh in April. A 3.4-MW electric cogeneration plant would produce 10.2 MW(t) and require a 12.75-MW boiler because of the 80% boiler efficiency. The plant would generate 22,560 MBtu(t) each month based on a 90% plant availability. The overall thermal energy capacity factor for a year would be fairly high (61%).

10. INPUT AND LCC SUMMARY SPREADSHEETS

SCOTT AFB: 1 X 40 MBtu/hr. ECONOMIC PARAMETERS - NOMINAL VALUES

Total steam output = 40.0 MBtu/hr
 Boiler capacity factor = .626
 Number of units for refit = 1
 Hydrated lime price (\$/ton) = 40.00
 Ash disposal price (\$/ton) = 10.00
 Electric price (cents/kWh) = 4.90
 Labor rate (k\$/yr) = 35.00
 Limestone price (\$/ton) = 20.00

FUEL PRICES
 Natural gas price (\$/MBtu) = 3.80
 #2 Oil price (\$/MBtu) = .00
 #6 Oil price (\$/MBtu) = 3.67

OPTIONS
 Soot blower multiplier = .0
 Tube bank mod multiplier = .0
 Bottom ash pit multiplier = 1.0
 SO2 control multiplier = 1.0

LIMESTONE/LIME
 Inert fraction = .05

COAL PROPERTIES
 R.O.M. Stoker
 Ash fraction = .112 .107
 Sulfur fraction = .037 .037
 HHV (Btu/lb) = 10310. 10690.

FUEL PRICES
 R.O.M. coal (\$/MBtu) = 1.24
 Stoker coal (\$/MBtu) = 1.26
 Coal/H2O mix (\$/MBtu) = 3.00
 Coal/oil mix (\$/MBtu) = 3.50

Primary fuel is 3
NATURAL GAS
 1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988
 Gen infla index (1987 to base yr) = 1.040
 Gas infla index (1988 to base yr) = 1.000
 Oil infla index (1988 to base yr) = 1.000
 Coal infla index (1988 to base yr) = 1.000
 Project start year = 1990
 Project life (yr) = 30
 Depreciation life (yr) = 15
 General inflation rate (X/yr) = 0
 Type of gas escalation = egas
 Type of oil escalation = eoil
 Type of coal escalation = ecoal
 Discount rate (X/yr) = 10
 Rate of return on invest (X/yr) = 17
 Amt of working capital (month) = 2
 Federal income tax rate (X) = 34
 Local prop tax (& insur) rate (X) = 2

| | | REAL ESCALATION RATE (X/yr) | | | |
|------|----------------------------|-----------------------------|-------|-------|----------|
| FUEL | TYPE OF FUEL ESCALATION | 1988 | 1990 | 1995 | 2000 AND |
| | | -1990 | -1995 | -2000 | BEYOND |
| Gas | egas | 3.89 | 8.87 | 5.77 | 5.77 |
| Oil | eoil | 4.86 | 7.87 | 4.16 | 4.16 |
| Coal | ecoal | 1.16 | 2.31 | 1.19 | 1.19 |

3:12 PM Oct 24, 1988

SCOTT AFB: 1 X 40 MBtu/hr. ECONOMIC PARAMETERS - NOMINAL VALUES

Total steam output = 40.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .626

Primary fuel = NATURAL GAS

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & H k\$ | OTHER O & H k\$ |
| | | | | | k\$ | k\$ | k\$ |
| Natural gas boiler | -- | .800 | 3.80 | .0 | 1041.9 | 146.3 | 445.0 |
| #2 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #6 Oil fired boiler | -- | .800 | 3.67 | .0 | 1006.3 | 146.3 | 445.0 |
| Micronized coal refit | 1 | .800 | 1.24 | 2779.1 | 340.0 | 339.8 | 765.6 |
| Slagging burner refit | 1 | .800 | 1.24 | 4438.7 | 340.0 | 339.8 | 765.6 |
| Modular FBC refit | 1 | .780 | 1.24 | 4995.3 | 344.3 | 323.4 | 732.8 |
| Stoker firing refit | 1 | .740 | 1.26 | 3958.8 | 373.5 | 498.5 | 694.7 |
| Coal/water slurry | 1 | .750 | 3.00 | 2545.7 | 877.4 | 323.4 | 688.7 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2166.5 | 984.3 | 257.5 | 562.1 |
| Low Btu gasifier refit | 1 | .659 | 1.26 | 4448.1 | 419.7 | 298.3 | 817.5 |
| Packaged shell stoker | 1 | .740 | 1.26 | 4405.5 | 373.5 | 498.5 | 694.7 |
| Packaged shell FBC | 1 | .760 | 1.24 | 4437.1 | 357.9 | 323.4 | 739.2 |
| Field erected stoker | 1 | .780 | 1.26 | 6656.2 | 354.3 | 496.5 | 683.8 |
| Field erected FBC | 1 | .800 | 1.24 | 6321.2 | 340.0 | 375.6 | 730.8 |
| Pulverized coal boiler | 1 | .800 | 1.24 | 7777.0 | 340.0 | 554.6 | 727.0 |
| Circulating FBC | 1 | .810 | 1.24 | 7407.7 | 335.8 | 321.4 | 734.8 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|---|------------------|--|---------------------|------------------------------------|--|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO | PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO |
| | | | k\$ | RATIO | yr | k\$ | RATIO |
| Natural gas boiler | -- | -- | 23,070 | 1.000 | <--- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 0 | -- | | | |
| #6 Oil fired boiler | -- | -- | 20,097 | -- | | | |
| Micronized coal refit | Not applicable because of space limitations | | | | | | |
| Slagging burner refit | Not applicable because of space limitations | | | | | | |
| Modular FBC refit | Not applicable because of space limitations | | | | | | |
| Stoker firing refit | Not applicable because of space limitations | | | | | | |
| Coal/water slurry | 1 | 13,914 | 18,558 | 1.243 | 14.6 | 20,323 | 1.135 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | Not applicable because of space limitations | | | | | | |
| Packaged shell stoker | 1 | 13,610 | 17,000 | 1.357 | 12.9 | 19,626 | 1.176 |
| Packaged shell FBC | 1 | 13,731 | 15,661 | 1.473 | 10.6 | 18,284 | 1.263 |
| Field erected stoker | 1 | 12,912 | 18,744 | 1.231 | 17.5 | 22,611 | 1.020 |
| Field erected FBC | 1 | 13,044 | 17,453 | 1.322 | 14.7 | 21,023 | 1.087 |
| Pulverized coal boiler | 1 | 13,044 | 20,227 | 1.141 | 21.4 | 24,585 | .938 |
| Circulating FBC | 1 | 12,883 | 17,858 | 1.292 | 15.9 | 21,968 | 1.050 |

3:12 PM Oct 24, 1988

SCOTT AFB: 1 X 40 MBtu/hr. FUEL REAL ESCALATION = ADO 1987

Total steam output = 40.0 MBtu/hr

Boiler capacity factor = .626

Number of units for refit = 1

Hydrated lime price (\$/ton) = 40.00

Ash disposal price (\$/ton) = 10.09

Electric price (cents/kWh) = 4.99

Labor rate (\$/yr) = 35.00

Limestone price (\$/ton) = 20.00

FUEL PRICES

Natural gas price (\$/MBtu) = 3.80

#2 Oil price (\$/MBtu) = .00

#6 Oil price (\$/MBtu) = 3.67

OPTIONS

Soot blower multiplier = .0

Tube bank mod multiplier = .0

Bottom ash pit multiplier = 1.0

SO2 control multiplier = 1.0

LIMESTONE/LIME

Inert fraction = .05

COAL PROPERTIESR.O.M. Stoker

Ash fraction = .112 .107

Sulfur fraction = .037 .037

HHV (Btu/lb) = 10510. 10630.

FUEL PRICES

R.O.M. coal (\$/MBtu) = 1.24

Stoker coal (\$/MBtu) = 1.26

Coal/H2O mix (\$/MBtu) = 3.00

Coal/oil mix (\$/MBtu) = 3.30

Primary fuel is 3

NATURAL GAS

1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988

Gen infla index (1987 to base yr) = 1.040

Gas infla index (1988 to base yr) = 1.000

Oil infla index (1988 to base yr) = 1.000

Coal infla index (1988 to base yr) = 1.000

Project start year = 1990

Project life (yr) = 30

Depreciation life (yr) = 15

General inflation rate (I/yr) = 0

Type of gas escalation = cgas

Type of oil escalation = eoil

Type of coal escalation = ecoal

Discount rate (I/yr) = 10

Rate of return on invest (I/yr) = 17

Amount of working capital (month) = 2

Federal income tax rate (I) = 34

Local prop tax (& insur) rate (I) = 2

| FUEL | TYPE OF FUEL ESCALATION | REAL ESCALATION RATE (I/yr) | | | |
|------|----------------------------|-----------------------------|---------------|---------------|--------------------|
| | | 1988 -1990 | 1990 -1995 | 1995 -2000 | 2000 AND BEYOND |
| Gas | egas | 2.25 | 4.70 | 5.49 | 2.75 |
| Oil | eoil | .17 | 4.16 | 5.55 | 2.77 |
| Coal | ecoal | 1.46 | 1.76 | 1.61 | .81 |

3:18 PM Oct 24, 1988

SCOTT AFB: 1 X 40 MBtu/hr. FUEL REAL ESCALATION - APR 1987

Total steam output = 40.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .826

Primary fuel = NATURAL GAS

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL \$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|------------------|--------------|----------------|----------------|
| | | | | | FUEL \$ | MAINT O & M \$ | OTHER O & M \$ |
| Natural gas boiler | -- | .800 | 3.80 | .0 | 1041.0 | 148.3 | 445.0 |
| #2 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #6 Oil fired boiler | -- | .800 | 3.67 | .0 | 1008.3 | 148.3 | 445.0 |
| Micronized coal refit | 1 | .800 | 1.24 | 2778.1 | 340.0 | 339.8 | 765.6 |
| Slagging burner refit | 1 | .800 | 1.24 | 4438.7 | 340.0 | 339.8 | 765.6 |
| Modular FBC refit | 1 | .780 | 1.24 | 4995.3 | 344.3 | 323.4 | 732.8 |
| Stoker firing refit | 1 | .740 | 1.26 | 3958.8 | 373.5 | 498.5 | 694.7 |
| Coal/water slurry | 1 | .750 | 3.00 | 2545.7 | 877.4 | 323.4 | 688.7 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2166.5 | 984.3 | 257.5 | 582.1 |
| Low Btu gasifier refit | 1 | .859 | 1.26 | 4448.1 | 419.7 | 299.3 | 317.5 |
| Packaged shell stoker | 1 | .740 | 1.26 | 4405.5 | 373.5 | 498.5 | 694.7 |
| Packaged shell FBC | 1 | .760 | 1.24 | 4437.1 | 357.9 | 323.4 | 739.2 |
| Field erected stoker | 1 | .780 | 1.26 | 6856.2 | 354.3 | 498.5 | 683.8 |
| Field erected FBC | 1 | .800 | 1.24 | 6321.2 | 340.0 | 375.6 | 730.8 |
| Pulverized coal boiler | 1 | .800 | 1.24 | 7777.9 | 340.0 | 554.6 | 727.3 |
| Circulating FBC | 1 | .810 | 1.24 | 7402.7 | 335.8 | 321.4 | 734.8 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|---|------------------|---|---------------------|------------------------------------|---|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT \$ | BENEFIT/ COST RATIO | PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT \$ | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 17,798 | 1.000 | <--- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 0 | -- | | | |
| #6 Oil fired boiler | -- | -- | 16,599 | -- | | | |
| Micronized coal refit | Not applicable because of space limitations | | | | | | |
| Slagging burner refit | Not applicable because of space limitations | | | | | | |
| Modular FBC refit | Not applicable because of space limitations | | | | | | |
| Stoker firing refit | Not applicable because of space limitations | | | | | | |
| Coal/water slurry | 1 | 13,914 | 18,419 | .968 | >31 | 20,170 | .882 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | Not applicable because of space limitations | | | | | | |
| Packaged shell stoker | 1 | 13,610 | 16,941 | 1.051 | 22.7 | 19,565 | .910 |
| Packaged shell FBC | 1 | 13,731 | 15,604 | 1.141 | 16.1 | 18,205 | .97~ |
| Field erected stoker | 1 | 12,912 | 18,687 | .952 | >31 | 22,553 | .786 |
| Field erected FBC | 1 | 13,044 | 17,399 | 1.023 | 26.9 | 20,967 | .849 |
| Pulverized coal boiler | 1 | 13,044 | 20,173 | .882 | >31 | 24,530 | .726 |
| Circulating FBC | 1 | 12,883 | 17,804 | 1.000 | >31 | 21,914 | .812 |

3:18 PM Oct 24, 1988

SCOTT AFB: 1 X 40 MBtu/hr. FUEL REAL ESCALATION = 1.00

Total steam output = 40.0 MBtu/hr

Boiler capacity factor = .828

Number of units for refit = 1

Hydrated lime price (\$/ton) = 40.00

Ash disposal price (\$/ton) = 10.00

Electric price (cents/kWh) = 4.90

Labor rate (k\$/yr) = 35.00

Limestone price (\$/ton) = 20.00

FUEL PRICES

Natural gas price (\$/MBtu) = 3.80

#2 Oil price (\$/MBtu) = .00

#5 Oil price (\$/MBtu) = 3.67

OPTIONS

Soot blower multiplier = .0

Tube bank mod multiplier = .0

Bottom ash pit multiplier = 1.0

SO2 control multiplier = 1.0

LIMESTONE/LIME

Inert fraction = .05

COAL PROPERTIESR.O.M. Stoker

Ash fraction = .112 .107

Sulfur fraction = .037 .037

HHV (Btu/lb) = 10510. 10890.

FUEL PRICES

R.O.M. coal (\$/MBtu) = 1.24

Stoker coal (\$/MBtu) = 1.28

Coal/H2O mix (\$/MBtu) = 3.00

Coal/oil mix (\$/MBtu) = 3.50

Primary fuel is 3

NATURAL GAS

1-#5 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988

Gen infla index (1987 to base yr) = 1.040

Gas infla index (1988 to base yr) = 1.000

Oil infla index (1988 to base yr) = 1.000

Coal infla index (1988 to base yr) = 1.000

Project start year = 1990

Project life (yr) = 30

Depreciation life (yr) = 15

General inflation rate (I/yr) = 0

Type of gas escalation = zero

Type of oil escalation = zero

Type of coal escalation = zero

Discount rate (I/yr) = 10

Rate of return on invest (I/yr) = 17

Amount of working capital (month) = 2

Federal income tax rate (I) = 34

Local prop tax (& insur) rate (I) = 2

| | | <u>REAL ESCALATION RATE (I/yr)</u> | | | |
|-------------|---------------------|------------------------------------|-------|-------|----------|
| | <u>TYPE OF FUEL</u> | 1988 | 1990 | 1995 | 2000 AND |
| <u>FUEL</u> | <u>ESCALATION</u> | -1990 | -1995 | -2000 | BEYOND |
| Gas | zero | 0 | 0 | 0 | 0 |
| Oil | zero | 0 | 0 | 0 | 0 |
| Coal | zero | 0 | 0 | 0 | 0 |

3:24 PM Oct 24, 1988

SCOTT AFB: 1 X 40 MBtu/hr. FUEL REAL ESCALATION = ZERO

Total steam output = 40.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .626

Primary fuel = NATURAL GAS

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | OTHER O & M k\$ |
| Natural gas boiler | -- | .800 | 3.80 | .0 | 1041.9 | 146.3 | 445.0 |
| #2 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #6 Oil fired boiler | -- | .800 | 3.07 | .0 | 1606.3 | 146.3 | 445.0 |
| Micronized coal refit | 1 | .800 | 1.24 | 2779.1 | 340.0 | 339.8 | 765.6 |
| Slagging burner refit | 1 | .800 | 1.24 | 4438.7 | 340.0 | 339.8 | 765.6 |
| Modular FBC refit | 1 | .780 | 1.24 | 4995.3 | 344.3 | 323.4 | 732.8 |
| Stoker firing refit | 1 | .740 | 1.26 | 3958.8 | 373.5 | 408.5 | 694.7 |
| Coal/water slurry | 1 | .750 | 3.00 | 2545.7 | 877.4 | 323.4 | 688.7 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2166.5 | 984.3 | 257.5 | 562.1 |
| Low Btu gasifier refit | 1 | .659 | 1.26 | 4448.1 | 419.7 | 298.3 | 817.5 |
| Packaged shell stoker | 1 | .740 | 1.26 | 4405.5 | 373.5 | 408.5 | 694.7 |
| Packaged shell FBC | 1 | .760 | 1.24 | 4437.1 | 357.9 | 323.4 | 739.2 |
| Field erected stoker | 1 | .780 | 1.26 | 6856.2 | 354.3 | 406.5 | 683.8 |
| Field erected FBC | 1 | .800 | 1.24 | 6321.2 | 340.0 | 375.6 | 730.8 |
| Pulverized coal boiler | 1 | .800 | 1.24 | 7777.9 | 340.0 | 554.6 | 727.0 |
| Circulating FBC | 1 | .810 | 1.24 | 7407.7 | 335.8 | 321.4 | 734.8 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|---|------------------|--|---------------------|------------------------------------|--|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO | PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 12,893 | 1.000 | <--- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 0 | -- | | | |
| #6 Oil fired boiler | -- | -- | 12,615 | -- | | | |
| Micronized coal refit | Not applicable because of space limitations | | | | | | |
| Slagging burner refit | Not applicable because of space limitations | | | | | | |
| Modular FBC refit | Not applicable because of space limitations | | | | | | |
| Stoker firing refit | Not applicable because of space limitations | | | | | | |
| Coal/water slurry | 1 | 13,914 | 17,197 | .750 | >31 | 18,923 | .681 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | Not applicable because of space limitations | | | | | | |
| Packaged shell stoker | 1 | 13,610 | 16,421 | .785 | >31 | 19,030 | .678 |
| Packaged shell FBC | 1 | 13,731 | 15,105 | .854 | >31 | 17,693 | .729 |
| Field erected stoker | 1 | 12,912 | 18,194 | .709 | >31 | 22,045 | .585 |
| Field erected FBC | 1 | 13,044 | 16,925 | .762 | >31 | 20,481 | .630 |
| Pulverized coal boiler | 1 | 13,044 | 19,700 | .654 | >31 | 24,043 | .536 |
| Circulating FBC | 1 | 12,883 | 17,337 | .744 | >31 | 21,433 | .602 |

3:24 PM Oct 24, 1988

GRAND FORKS AFB: SAC

1. BACKGROUND

Grand Forks AFB is located near Grand Forks, North Dakota. The central steam plant is the only one of interest to this study. There are five boilers sized at 3 x 25 MBtu/h and 2 x 42 MBtu/h. Hot water is produced at 395°F. All boilers in this steam plant were designed for stoker coal-firing but were later converted to burn No. 6 oil.

Currently an electric boiler system is supplying steam by a special agreement with the local utility. Apparently, the utility will supply electricity for steam generation at a very reduced price (\$0.0215/kWh). Because Tim Fry says this may not last much longer, the LCC analysis was performed assuming that No. 6 oil is the primary fuel.

The yearly average electric use is roughly 45 MBtu/h. Boiler efficiency is reported to be about 65-76%. No coal equipment is left.

2. HEATING PLANT UNITS

Heating Plant No. 423:

2 x 25 MBtu/h, Combustion Engineering, 1956
 25 and 42 MBtu/h, International Boiler Works, 1958
 42 MBtu/h, International Boiler Works, 1964

3. IDEAL CAPACITY FACTOR ANALYSIS

The ideal capacity factors listed below were calculated from monthly electric-use data for plant No. 423.

| Electric input (MBtu/h) | FY 1985 ideal capacity factor | FY 1986 ideal capacity factor |
|-------------------------------|--|--|
| 40 | 0.81 | 0.82 |
| 50 | 0.74 | 0.76 |
| 60 | 0.68 | 0.70 |
| 70 | 0.63 | 0.64 |
| 90 | 0.51 | 0.53 |

4. ENERGY PRICES

FY 1986 Price Data:

Electricity = 4.2¢/kWh (regular price)
 Distillate = \$5.41/MBtu
 Natural gas = \$3.64/MBtu

C. H. Guernsey and Co. Survey:

Electricity = 2.15¢/kWh (\$6.3/MBtu, special price for steam generation)

Distillate = \$6.07/MBtu (\$0.91/gal)

5. COAL PROPERTIES AND PRICES

| | <u>Stoker</u> | <u>ROM</u> |
|-------------------------------------|----------------|----------------|
| Origin | Morhland, Utah | Morhland, Utah |
| HHV, Btu/lb | 12,300 | 12,200 |
| % Ash | 8 | 8 |
| % Sulfur | 1 | 1 |
| % Nitrogen | 1.2 | 1.2 |
| Ash-softening temperature, °F | 2300 | 2300 |
| Swelling index | 1 | 1 |
| Top size, in. | 1 1/4 | 1 1/2 |
| Bottom size, in. | 1/4 | 0 |
| Fines, % | 10 | 45 |
| Grindability index | 41 | 41 |
| Cost at mine, \$/ton | 32 | 22 |
| Delivered cost, \$/ton | 46 | 36 |
| Energy cost, \$/10 ⁶ Btu | 1.87 | 1.48 |

6. ENVIRONMENTAL REGULATIONS

6.1 Air Pollution Emission Limits for New Sources

SO₂. For boilers >30 and <100 MBtu/h: 3 lb/MBtu.

NO_x. For boilers >30 and <100 MBtu/h: No emission limit.

Particulates. For boilers >30 and <100 MBtu/h:

$$E = 0.811 (\text{MBtu/h})^{0.131}$$

For 42 MBtu/h: 0.5 lb/MBtu.

6.2 Coal-Pile Runoff

Limit: Total suspended solids - 50 mg/L.

6.3 Ash Disposal

Ashes are classified as nonhazardous industrial solid waste and may be disposed of in any approved sanitary landfill.

7. OTHER CONSIDERATIONS

This base is located near sources of lignite. The low-cost electricity scheme for the electric system boiler may stop in the near future.

8. COAL-CONVERSION PROJECT OUTLOOK

A refit/replacement project for one of the 42-MBtu/h output (equivalent to 43 MBtu/h electric input) boilers may be economically attractive. An overall capacity factor near 72% is expected, assuming a 90% availability.

8.1 Effect of Environmental Regulations on Selection of Combustion Technologies

SO₂ and NO_x. Any of the combustion technologies being considered could be employed without requiring any measures for NO_x or SO₂ reduction since the proposed conversion project is smaller than 100 MBtu/h and the coal has a low sulfur content.

Particulates. Bag filters or electrostatic precipitators would be required to comply with the particulate emission limits.

8.2 Physical Space and Aesthetics

Heating Plant. The existing boiler plant was originally designed for coal. There is space available for reinstalling coal-combustion equipment at the existing boiler or for construction of a new boiler at another site on base.

Coal-Handling Equipment. There is space available for installing coal-handling equipment at the existing boiler.

Coal Pile. There is space available for a coal pile at the existing boiler plant or at a new site on base.

8.3 Technical Risk of Combustion Technologies

The least technical risk would be for refit of stoker firing to the existing boiler, since it was originally designed for this, or installation of a new stoker-fired boiler. The other technologies would have greater technical risks because of lack of operating experience, and all of them would be of the same order since the existing boiler is designed for coal firing.

9. COGENERATION PROJECT OUTLOOK

Cogeneration would not be economical at this base because of the very low electric power rates.

10. INPUT AND LCC SUMMARY SPREADSHEETS

GRAND FORKS AVE: 1 X 42 MBtu/hr #6 BOILER. ECONOMIC PARAM - NOMINAL VALUES

Total steam output = 42.0 MBtu/hr

Boiler capacity factor = .716

Number of units for refit = 1

Hydrated lime price (\$/ton) = 40.00

Ash disposal price (\$/ton) = 10.00

Electric price (cents/kWh) = 4.20

Labor rate (k\$/yr) = 35.00

Limestone price (\$/ton) = 20.00

FUEL PRICES

Natural gas price (\$/MBtu) = .00

#2 Oil price (\$/MBtu) = .00

#6 Oil price (\$/MBtu) = 3.67

OPTIONS

Soot blower multiplier = .0

Tube bank mod multiplier = .0

Bottom ash pit multiplier = 1.0

SO2 control multiplier = .0

LIMESTONE/LIME

Inert fraction = .05

COAL PROPERTIES**R.O.M. Stoker**

Ash fraction = .080 .080

Sulfur fraction = .010 .010

HHV (Btu/lb) = 12200. 12300.

FUEL PRICES

R.O.M. coal (\$/MBtu) = 1.48

Stoker coal (\$/MBtu) = 1.97

Coal/H2O mix (\$/MBtu) = 3.00

Coal/oil mix (\$/MBtu) = 3.50

Primary fuel is 1

#6 FUEL OIL

1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988

Gen infla index (1987 to base yr) = 1.040

Gas infla index (1988 to base yr) = 1.000

Oil infla index (1988 to base yr) = 1.000

Coal infla index (1908 to base yr) = 1.000

Project start year = 1990

Project life (yr) = 30

Depreciation life (yr) = 15

General inflation rate (X/yr) = 0

Type of gas escalation = egas

Type of oil escalation = eoil

Type of coal escalation = ecoal

Discount rate (X/yr) = 10

Rate of return on invest (X/yr) = 17

Amount of working capital (month) = 2

Federal income tax rate (%) = 34

Local prop tax (& insur) rate (%) = 2

| | | REAL ESCALATION RATE (X/yr) | | | |
|------|----------------------------|-----------------------------|-------|-------|----------|
| FUEL | TYPE OF FUEL ESCALATION | 1988 | 1990 | 1995 | 2000 AND |
| | | -1990 | -1995 | -2000 | BEYOND |
| Gas | egas | 3.89 | 8.87 | 5.77 | 5.77 |
| Oil | eoil | 4.86 | 7.87 | 4.17 | 4.16 |
| Coal | ecoal | 1.16 | 2.31 | 1.19 | 1.19 |

2:52 PM Oct 19, 1988

GRAND FORKS AFB: 1 X 42 MBtu/hr #6 BOILER. ECONOMIC PARAM - NOMINAL VALUES

Total steam output = 42.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .715

Primary fuel = #6 FUEL OIL

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | OTHER O & M k\$ |
| Natural gas boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #2 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #6 Oil fired boiler | -- | .800 | 3.67 | .0 | 1208.5 | 150.3 | 448.5 |
| Micronized coal refit | 1 | .800 | 1.48 | 2319.2 | 487.3 | 345.8 | 600.0 |
| Slagging burner refit | 1 | .800 | 1.48 | 4026.2 | 487.3 | 345.8 | 600.0 |
| Modular FBC refit | 1 | .780 | 1.48 | 4631.1 | 403.5 | 329.1 | 587.2 |
| Stoker firing refit | 1 | .760 | 1.87 | 2779.8 | 648.2 | 329.1 | 580.9 |
| Coal/water slurry | 1 | .750 | 3.00 | 2068.4 | 1053.7 | 329.1 | 510.6 |
| Coal/oil slurry | 1 | .780 | 3.50 | 1835.9 | 1182.1 | 282.1 | 486.2 |
| Low Btu gasifier refit | 1 | .679 | 1.87 | 3777.4 | 725.9 | 303.5 | 675.7 |
| Packaged shell stoker | 1 | .760 | 1.87 | 3240.1 | 648.2 | 329.1 | 580.9 |
| Packaged shell FBC | 1 | .780 | 1.48 | 4060.1 | 513.0 | 329.1 | 587.6 |
| Field erected stoker | 1 | .800 | 1.87 | 5845.8 | 615.8 | 327.1 | 575.6 |
| Field erected FBC | 1 | .800 | 1.48 | 6405.1 | 487.3 | 382.2 | 587.1 |
| Pulverized coal boiler | 1 | .820 | 1.48 | 6797.0 | 475.5 | 386.2 | 616.8 |
| Circulating FBC | 1 | .810 | 1.48 | 7556.0 | 481.3 | 327.1 | 637.7 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|---------------|------------------|--|---------------------|------------------------------------|--|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO | PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 0 | -- | | | |
| #2 Oil fired boiler | -- | -- | 0 | -- | | | |
| #6 Oil fired boiler | -- | -- | 23,239 | 1.000 | <--- Existing system, primary fuel | | |
| Micronized coal refit | 1 | 13,485 | 14,236 | 1.632 | 5.4 | 15,768 | 1.474 |
| Slagging burner refit | 1 | 13,485 | 15,647 | 1.485 | 8.1 | 18,050 | 1.288 |
| Modular FBC refit | 1 | 13,666 | 15,956 | 1.456 | 8.9 | 18,661 | 1.245 |
| Stoker firing refit | 1 | 14,080 | 15,822 | 1.469 | 7.1 | 17,623 | 1.319 |
| Coal/water slurry | 1 | 14,385 | 18,475 | 1.258 | 9.9 | 20,005 | 1.162 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | 1 | 15,780 | 17,882 | 1.300 | 10.8 | 20,227 | 1.149 |
| Packaged shell stoker | 1 | 14,080 | 16,202 | 1.434 | 7.9 | 18,238 | 1.274 |
| Packaged shell FBC | 1 | 14,206 | 15,669 | 1.483 | 8.1 | 18,089 | 1.285 |
| Field erected stoker | 1 | 13,386 | 17,989 | 1.292 | 12.6 | 21,343 | 1.089 |
| Field erected FBC | 1 | 13,485 | 17,838 | 1.303 | 12.8 | 21,460 | 1.083 |
| Pulverized coal boiler | 1 | 13,166 | 18,318 | 1.269 | 13.8 | 22,145 | 1.049 |
| Circulating FBC | 1 | 13,329 | 18,634 | 1.247 | 14.8 | 22,839 | 1.018 |

GRAND FORKS AFB: 1 X 42 MBtu/hr #6 BOILER. FUEL REAL ESCALATION - AEO 1987

Total steam output = 42.0 MBtu/hr

Boiler capacity factor = .716

Number of units for refit = 1

Hydrated lime price (\$/ton) = 40.00

Ash disposal price (\$/ton) = 10.00

Electric price (cents/kWh) = 4.20

Labor rate (k\$/yr) = 35.00

Limestone price (\$/ton) = 20.00

FUEL PRICES

Natural gas price (\$/MBtu) = .00

#2 Oil price (\$/MBtu) = .00

#6 Oil price (\$/MBtu) = 3.67

OPTIONS

Soot blower multiplier = .0

Tube bank mod multiplier = .0

Bottom ash pit multiplier = 1.0

SO₂ control multiplier = .0**LIMESTONE/LIME**

Inert fraction = .05

COAL PROPERTIES**R.O.M. Stoker**

Ash fraction = .080 .080

Sulfur fraction = .010 .010

HHV (Btu/lb) = 12200. 12300.

FUEL PRICES

R.O.M. coal (\$/MBtu) = 1.48

Stoker coal (\$/MBtu) = 1.87

Coal/H₂O mix (\$/MBtu) = 3.00

Coal/oil mix (\$/MBtu) = 3.50

Primary fuel is 1

#6 FUEL OIL

1-#6 Oil, 2-#2 Oil, 3-WG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988

Gen infla index (1987 to base yr) = 1.040

Gas infla index (1988 to base yr) = 1.000

Oil infla index (1988 to base yr) = 1.000

Coal infla index (1988 to base yr) = 1.000

Project start year = 1990

Project life (yr) = 30

Depreciation life (yr) = 15

General inflation rate (I/yr) = 0

Type of gas escalation = egas

Type of oil escalation = eoil

Type of coal escalation = ecoal

Discount rate (I/yr) = 10

Rate of return on invest (I/yr) = 17

Amount of working capital (month) = 2

Federal income tax rate (I) = 34

Local prop tax (& insur) rate (I) = 2

| FUEL | TYPE OF FUEL ESCALATION | REAL ESCALATION RATE (I/yr) | | | |
|------|----------------------------|-----------------------------|---------------|---------------|--------------------|
| | | 1988 -1990 | 1990 -1995 | 1995 -2000 | 2000 AND BEYOND |
| Gas | egas | 2.28 | 4.70 | 5.49 | 2.75 |
| Oil | eoil | .17 | 4.16 | 5.55 | 2.77 |
| Coal | ecoal | 1.46 | 1.76 | 1.61 | .81 |

3:07 PM Oct 19, 1988

GRAND FORKS AFB: 1 X 42 Mtu/hr #6 BOILER. FUEL COST EVALUATION - AEO 1987

Total steam output = 27.0 Mtu/hr

Cost base year = 1988

Boiler capacity factor = .716

Primary fuel = #6 FUEL OIL

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/STEAM EFF | FUEL PRICE \$/Mtu | TOTAL CAPITAL \$ | ANNUAL COSTS | | |
|------------------------|------------|----------------|-------------------|------------------|--------------|----------------|----------------|
| | | | | | FUEL \$ | MAINT O & M \$ | OTHER O & M \$ |
| Natural gas boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #2 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #6 Oil fired boiler | -- | .800 | 1.87 | .0 | 1208.5 | 150.3 | 448.5 |
| Micronized coal refit | 1 | .800 | 1.48 | 2319.2 | 487.3 | 345.8 | 800.0 |
| Slagging burner refit | 1 | .800 | 1.48 | 4026.2 | 487.3 | 345.8 | 800.0 |
| Modular FBC refit | 1 | .790 | 1.48 | 4631.1 | 493.5 | 329.1 | 587.2 |
| Stoker firing refit | 1 | .780 | 1.37 | 2779.8 | 648.2 | 329.1 | 580.9 |
| Coal/water slurry | 1 | .750 | 3.00 | 2068.4 | 1053.7 | 329.1 | 510.6 |
| Coal/oil slurry | 1 | .780 | 3.50 | 1835.9 | 1182.1 | 262.1 | 486.2 |
| Low Btu gasifier refit | 1 | .879 | 1.47 | 3777.4 | 725.9 | 303.5 | 875.7 |
| Packaged shell stoker | 1 | .780 | 1.87 | 3240.1 | 648.2 | 329.1 | 580.9 |
| Packaged shell FBC | 1 | .780 | 1.48 | 4060.1 | 513.0 | 329.1 | 587.6 |
| Field erected stoker | 1 | .800 | 1.87 | 5845.8 | 615.8 | 327.1 | 575.0 |
| Field erected FBC | 1 | .800 | 1.48 | 6403.1 | 487.3 | 382.2 | 587.1 |
| Pulverized coal boiler | 1 | .820 | 1.48 | 6787.0 | 475.5 | 386.2 | 616.8 |
| Circulating FBC | 1 | .810 | 1.48 | 7556.0 | 481.3 | 327.1 | 637.7 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|---------------|------------------|---|--------------------|------------------------------------|---|--------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT \$ | BENEFIT/COST RATIO | PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT \$ | BENEFIT/COST RATIO |
| Natural gas boiler | -- | -- | 0 | -- | | | |
| #2 Oil fired boiler | -- | -- | 0 | -- | | | |
| #6 Oil fired boiler | -- | -- | 19,638 | 1.000 | <--- Existing system, primary fuel | | |
| Micronized coal refit | 1 | 13,495 | 14,159 | 1.345 | 7.8 | 15,689 | 1.213 |
| Slagging burner refit | 1 | 13,495 | 15,570 | 1.223 | 12.3 | 17,970 | 1.059 |
| Modular FBC refit | 1 | 13,666 | 15,877 | 1.169 | 13.5 | 18,581 | 1.025 |
| Stoker firing refit | 1 | 14,090 | 15,719 | 1.211 | 11.3 | 17,517 | 1.087 |
| Coal/water slurry | 1 | 14,395 | 18,307 | 1.040 | 22.5 | 19,833 | .960 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | 1 | 15,780 | 17,767 | 1.072 | 20.1 | 20,108 | .947 |
| Packaged shell stoker | 1 | 14,090 | 16,099 | 1.183 | 12.6 | 18,132 | 1.050 |
| Packaged shell FBC | 1 | 14,206 | 15,588 | 1.221 | 12.3 | 18,005 | 1.057 |
| Field erected stoker | 1 | 13,386 | 17,891 | 1.064 | 21.9 | 21,242 | .896 |
| Field erected FBC | 1 | 13,495 | 17,760 | 1.072 | 21.5 | 21,380 | .890 |
| Pulverized coal boiler | 1 | 13,166 | 18,243 | 1.044 | 24.4 | 22,067 | .863 |
| Circulating FBC | 1 | 13,329 | 18,558 | 1.026 | 26.8 | 22,761 | .836 |

GRAND TOTALS ARE: 1 X 42 MBtu/hr #6 BOILER. FUEL REAL ESCALATION = ZERO

Total steam output = 42.0 MBtu/hr

Boiler capacity factor = .716

Number of units for refit = 1

Hydrated lime price (\$/ton) = 40.00

Ash disposal price (\$/ton) = 10.00

Electric price (cents/kWh) = 4.20

Labor rate (\$/yr) = 35.00

Limestone price (\$/ton) = 20.00

FUEL PRICES

Natural gas price (\$/MBtu) = .00

#2 Oil price (\$/MBtu) = .00

#6 Oil price (\$/MBtu) = 3.67

OPTIONS

Soot blower multiplier = .0

Tube bank mod multiplier = .0

Bottom ash pit multiplier = 1.0

SO2 control multiplier = .0

LIMESTONE/LIME

Inert fraction = .05

COAL PROPERTIES

R.O.M. Stoker

Ash fraction = .080 .080

Sulfur fraction = .010 .010

HHV (Btu/lb) = 12200. 12300.

FUEL PRICES

R.O.M. coal (\$/MBtu) = 1.48

Stoker coal (\$/MBtu) = 1.87

Coal/H2O mix (\$/MBtu) = 3.00

Coal/oil mix (\$/MBtu) = 3.30

Primary fuel is 1

#6 FUEL OIL

1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988

Gen infla index (1987 to base yr) = 1.040

Gas infla index (1988 to base yr) = 1.000

Oil infla index (1988 to base yr) = 1.000

Coal infla index (1988 to base yr) = 1.000

Project start year = 1990

Project life (yr) = 30

Depreciation life (yr) = 15

General inflation rate (I/yr) = 0

Type of gas escalation = zero

Type of oil escalation = zero

Type of coal escalation = zero

Discount rate (I/yr) = 10

Rate of return on invest (I/yr) = 17

Amount of working capital (month) = 2

Federal income tax rate (I) = 34

Local prop tax (& insur) rate (I) = 2

| | | REAL ESCALATION RATE (I/yr) | | | |
|------|----------------------------|-----------------------------|-------|-------|----------|
| FUEL | TYPE OF FUEL ESCALATION | 1988 | 1990 | 1995 | 2000 AND |
| | | -1990 | -1995 | -2000 | BEYOND |
| Gas | zero | 0 | 0 | 0 | 0 |
| Oil | zero | 0 | 0 | 0 | 0 |
| Coal | zero | 0 | 0 | 0 | 0 |

3:13 PM Oct 19, 1988

GRAND FORKS AFB: 1 X 42 Mtu/hr #6 BOILER FUEL REAL ESCALATION = ZERO

Total steam output = 42.0 Mtu/hr

Cost base year = 1988

Boiler capacity factor = .716

Primary fuel = #6 FUEL OIL

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/Mtu | TOTAL CAPITAL \$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|-------------------|------------------|--------------|----------------|----------------|
| | | | | | FUEL \$ | MAINT O & M \$ | OTHER O & M \$ |
| Natural gas boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #2 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #6 Oil fired boiler | -- | .800 | 3.67 | .0 | 1208.3 | 130.3 | 448.5 |
| Micronized coal refit | 1 | .800 | 1.48 | 2319.2 | 487.3 | 345.8 | 600.0 |
| Slagging burner refit | 1 | .800 | 1.48 | 4026.2 | 487.3 | 345.8 | 600.0 |
| Modular FBC refit | 1 | .780 | 1.48 | 4631.1 | 493.5 | 329.1 | 587.2 |
| Stoker firing refit | 1 | .780 | 1.47 | 2779.8 | 648.2 | 329.1 | 580.9 |
| Coal/water slurry | 1 | .750 | 3.00 | 2088.4 | 1053.7 | 329.1 | 510.6 |
| Coal/oil slurry | 1 | .780 | 3.50 | 1835.9 | 1182.1 | 262.1 | 486.2 |
| Low Btu gasifier refit | 1 | .879 | 1.87 | 3777.4 | 725.9 | 303.5 | 875.7 |
| Packaged shell stoker | 1 | .780 | 1.87 | 3240.1 | 648.2 | 329.1 | 550.9 |
| Packaged shell FBC | 1 | .780 | 1.48 | 4060.1 | 513.0 | 329.1 | 587.6 |
| Field erected stoker | 1 | .800 | 1.87 | 5845.8 | 615.8 | 327.1 | 575.0 |
| Field erected FBC | 1 | .800 | 1.48 | 8405.1 | 487.3 | 382.2 | 587.1 |
| Pulverized coal boiler | 1 | .820 | 1.48 | 6797.0 | 475.5 | 386.2 | 616.8 |
| Circulating FBC | 1 | .819 | 1.48 | 7558.0 | 481.3 | 327.1 | 637.7 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|---------------|------------------|---|---------------------|------------------------------------|---|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT \$ | BENEFIT/ COST RATIO | DISCOUNTED PAYBACK PERIOD, Yr | LIFE CYCLE COST, DISCOUNTED AS SPENT \$ | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 0 | -- | | | |
| #2 Oil fired boiler | -- | -- | 0 | -- | | | |
| #6 Oil fired boiler | -- | -- | 14,253 | 1.000 | <--- Existing system, primary fuel | | |
| Micronized coal refit | 1 | 13,495 | 13,480 | 1.057 | 12.9 | 14,991 | .951 |
| Slagging burner refit | 1 | 13,495 | 14,891 | .957 | >31 | 17,272 | .825 |
| Modular FBC refit | 1 | 13,668 | 15,190 | .938 | >31 | 17,874 | .787 |
| Stoker firing refit | 1 | 14,090 | 14,816 | .962 | >31 | 16,588 | .859 |
| Coal/water slurry | 1 | 14,395 | 16,840 | .846 | >31 | 18,323 | .778 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | 1 | 15,780 | 16,755 | .851 | >31 | 19,068 | .747 |
| Packaged shell stoker | 1 | 14,090 | 15,196 | .938 | >31 | 17,203 | .829 |
| Packaged shell FBC | 1 | 14,206 | 14,873 | .958 | >31 | 17,270 | .825 |
| Field erected stoker | 1 | 13,386 | 17,033 | .837 | >31 | 20,360 | .700 |
| Field erected FBC | 1 | 13,495 | 17,082 | .834 | >31 | 20,682 | .689 |
| Pulverized coal boiler | 1 | 13,166 | 17,581 | .811 | >31 | 21,386 | .666 |
| Circulating FBC | 1 | 13,329 | 17,887 | .797 | >31 | 22,071 | .646 |

3:13 PM Oct 19, 1988

MINOT: SAC

1. BACKGROUND

Minot AFB is located near Minot, North Dakota. The central heating plant is of interest for this study. The base hospital also has a heating plant which is far too small for coal-firing consideration.

The central heating plant has six water-tube boilers that burn natural gas or No. 6 oil (for backup) to produce 400°F hot water. Two boilers (42 and 25 MBtu/h) originally burned coal and were later converted to burn gas or oil; the remaining boilers were designed for residual oil. No coal equipment is still present. Yearly average fuel use is about 50 MBtu/h.

2. HEATING PLANT UNITS

Heating Plant No. 413:

2 x 25 MBtu/h, International Boiler Works, 1956
 25 MBtu/h, International Boiler Works, 1960
 2 x 25 MBtu/h, Combustion Engineering, 1957
 42 MBtu/h, Babcock & Wilcox, 1963

3. IDEAL CAPACITY FACTOR ANALYSIS

Based on monthly fuel-use data, the ideal capacity factors listed below were calculated for plant No. 413.

| Fuel input (MBtu/h) | FY 1985 ideal capacity factor | FY 1988 ideal capacity factor |
|---------------------------|--|--|
| 40 | 0.79 | 0.78 |
| 50 | 0.75 | 0.73 |
| 60 | 0.70 | 0.68 |
| 70 | 0.66 | 0.63 |
| 80 | 0.61 | 0.58 |
| 90 | 0.57 | 0.53 |
| 100 | 0.53 | 0.48 |

4. ENERGY PRICES

FY 1986 Price Data:

Electricity = 3.2¢/kWhr
 Distillate = \$5.90/MBtu
 Natural gas = \$3.90/MBtu

The data show no residual oil was purchased in FY 1986.

C. H. Guernsey and Co. Survey:

Electricity = 1.45¢/kWh
 Residual = \$2.53/MBtu (looks suspect)
 Natural gas = \$4.18/MBtu

The C. H. Guernsey and Co. survey gives No. 6 as the secondary fuel, costing only \$0.38/gal. The survey also gives electricity as being very cheap. It is possible that the oil was purchased when oil prices were very low.

Letter from HQ SAC (10/27/88):

Electricity = 1.52¢/kWh
 Natural gas = \$3.60/MBtu

5. COAL PROPERTIES AND PRICES

| | <u>Stoker</u> | <u>ROM</u> |
|-------------------------------------|----------------|----------------|
| Origin | Morhland, Utah | Morhland, Utah |
| HHV, Btu/lb | 12,300 | 12,200 |
| % Ash | 8 | 8 |
| % Sulfur | 1 | 1 |
| % Nitrogen | 1.2 | 1.2 |
| Ash-softening temperature, °F | 2300 | 2300 |
| Swelling index | 1 | 1 |
| Top size, in. | 1 1/4 | 1 1/2 |
| Bottom size, in. | 1/4 | 0 |
| Fines, % | 10 | 45 |
| Grindability index | 41 | 41 |
| Cost at mine, \$/ton | 32 | 22 |
| Delivered cost, \$/ton | 46 | 36 |
| Energy cost, \$/10 ⁶ Btu | 1.87 | 1.48 |

6. ENVIRONMENTAL REGULATIONS

6.1 Air Pollution Emission Limits for New Sources

SO₂. For boilers >30 and <100 MBtu/h: 3 lb/MBtu.

NO_x. No emissio. limits for boilers >30 and <100 MBtu/h.

Particulates. For boilers >30 and <100 MBtu/h:
 $E = 0.811 (\text{MBtu/h})^{-0.131} = 0.5 \text{ lb/MBtu for } 42 \text{ MBtu/h.}$

6.2 Coal-Pile Runoff

Limit: Total suspended solids - 50 mg/L.

6.3 Ash Disposal

Ashes are classified as nonhazardous industrial solid waste and may be disposed of in any approved sanitary landfill.

7. OTHER CONSIDERATIONS

This base is situated near sources of lignite.

8. COAL-CONVERSION PROJECT OUTLOOK

An obvious project would be to convert/replace the 42-MBtu/h unit (~54 MBtu/h fuel input). The overall capacity factor, assuming a 90% availability, is estimated to be about 65%.

8.1 Effect of Environmental Regulations on Selection of Combustion Technologies

SO₂ and NO_x. Any of the combustion technologies being considered could be employed without requiring any measures for NO_x or SO₂ reduction since the proposed conversion project is smaller than 100 MBtu/h and the coal has a low sulfur content.

Particulates. Bag filters or electrostatic precipitators would be required to comply with the particulate emission limits.

8.2 Physical Space and Aesthetics

Heating Plant. The existing boiler plant was originally designed for coal. There is space available for reinstalling combustion equipment at the existing boiler or for construction of a new boiler at another site on base.

Coal-Handling Equipment. There is space available for installing coal-handling equipment at the existing boiler.

Coal Pile. There is space available for a coal pile at the existing boiler plant or at a new site on base.

8.3 Technical Risk of Combustion Technologies

The least technical risk would be for refit of stoker firing to the existing boiler, since it was originally designed for this, or installation of a new stoker-fired boiler. The other technologies would have greater technical risks because of lack of operating experience, and all of them would be of the same order since the existing boiler is designed for coal firing.

9. COGENERATION PROJECT OUTLOOK

Cogeneration would not be economical at this base because of the very low electric power rates from the electric utility company.

10. INPUT AND LCC SUMMARY SPREADSHEETS

MINOT AVE: 1 X 42 MBtu/hr. ECONOMIC PARAMETERS - NOMINAL VALUES

| | | |
|--------------------------------------|-------------------------------|----------------------|
| Total steam output = 42.0 | MBtu/hr | |
| Boiler capacity factor = .84 | | |
| Number of units for refit = 1 | | |
| Hydrated lime price (\$/ton) = 40.00 | | |
| Ash disposal price (\$/ton) = 10.00 | | |
| Electric price (cents/kWh) = 1.50 | | |
| Labor rate (\$/yr) = 35.00 | | |
| Limestone price (\$/ton) = 20.00 | | |
| FUEL PRICES | | |
| Natural gas price (\$/MBtu) = 3.60 | | |
| #2 Oil price (\$/MBtu) = .00 | | |
| #6 Oil price (\$/MBtu) = 3.67 | | |
| OPTIONS | | |
| Soot blower multiplier = .0 | | |
| Tube bank mod multiplier = .0 | | |
| Bottom ash pit multiplier = 1.0 | | |
| SO2 control multiplier = .0 | | |
| LIMESTONE/LIME | | |
| Inert fraction = .05 | | |
| | COAL PROPERTIES | |
| | | R.O.M. Stoker |
| | Ash fraction = .080 | .080 |
| | Sulfur fraction = .010 | .010 |
| | HHV (Btu/lb) = 12200. | 12300. |
| | FUEL PRICES | |
| | R.O.M. coal (\$/MBtu) = 1.48 | |
| | Stoker coal (\$/MBtu) = 1.87 | |
| | Coal/H2O mix (\$/MBtu) = 3.00 | |
| | Coal/oil mix (\$/MBtu) = 3.50 | |
| | Primary fuel is 3 | |
| | NATURAL GAS | |
| | 1-#6 Oil, 2-#2 Oil, 3-NG | |

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988
 Gen infla index (1987 to base yr) = 1.040
 Gas infla index (1988 to base yr) = 1.000
 Oil infla index (1988 to base yr) = 1.000
 Coal infla index (1988 to base yr) = 1.000
 Project start year = 1990
 Project life (yr) = 30
 Depreciation life (yr) = 15
 General inflation rate (I/yr) = 0
 Type of gas escalation = egas
 Type of oil escalation = eoil
 Type of coal escalation = ecoal
 Discount rate (I/yr) = 10
 Rate of return on invest (I/yr) = 17
 Amount of working capital (month) = 2
 Federal income tax rate (I) = 34
 Local prop tax (& insur) rate (I) = 2

| | | REAL ESCALATION RATE (I/yr) | | | |
|------|----------------------------|-----------------------------|-------|-------|----------|
| FUEL | TYPE OF FUEL ESCALATION | 1988 | 1989 | 1995 | 2000 AND |
| | | -1990 | -1995 | -2000 | BEYOND |
| Gas | egas | 3.89 | 6.87 | 5.77 | 5.77 |
| Oil | eoil | 4.86 | 7.87 | 4.16 | 4.16 |
| Coal | ecoal | 1.16 | 2.31 | 1.19 | 1.19 |

2:06 PM Jan 4, 1989

MINOT AFB: 1 X 42 MBtu/hr. ECONOMIC PARAMETERS - NOMINAL VALUES

Total steam output = 42.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .845

Primary fuel = NATURAL GAS

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | OTHER O & M k\$ |
| Natural gas boiler | -- | .800 | 3.60 | .0 | 1089.5 | 150.3 | 427.6 |
| #2 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #6 Oil fired boiler | -- | .800 | 3.67 | .0 | 1090.3 | 150.3 | 427.6 |
| Micronized coal refit | 1 | .800 | 1.48 | 2319.2 | 439.7 | 345.8 | 557.4 |
| Slagging burner refit | 1 | .800 | 1.48 | 4026.2 | 439.7 | 345.8 | 557.4 |
| Modular FBC refit | 1 | .790 | 1.48 | 4631.1 | 445.3 | 329.1 | 553.4 |
| Stoker firing refit | 1 | .760 | 1.87 | 2779.8 | 584.8 | 329.1 | 551.6 |
| Coal/water slurry | 1 | .750 | 3.00 | 2088.4 | 950.7 | 329.1 | 481.3 |
| Coal/oil slurry | 1 | .780 | 3.50 | 1835.9 | 1066.5 | 262.1 | 457.5 |
| Low Btu gasifier refit | 1 | .679 | 1.87 | 3777.4 | 855.0 | 303.5 | 584.5 |
| Packaged shell stoker | 1 | .760 | 1.87 | 3240.1 | 584.8 | 329.1 | 551.6 |
| Packaged shell FBC | 1 | .760 | 1.48 | 4060.1 | 462.8 | 329.1 | 553.8 |
| Field erected stoker | 1 | .800 | 1.87 | 5845.8 | 555.6 | 327.1 | 549.2 |
| Field erected FBC | 1 | .800 | 1.48 | 6405.1 | 439.7 | 382.2 | 553.3 |
| Pulverized coal boiler | 1 | .820 | 1.48 | 6797.0 | 429.0 | 386.2 | 586.4 |
| Circulating FBC | 1 | .810 | 1.48 | 7556.0 | 434.3 | 327.1 | 593.2 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|---------------|------------------|--|--------------------|------------------------------------|--|--------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/COST RATIO | DISCOUNTED PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/COST RATIO |
| Natural gas boiler | -- | -- | 23,436 | 1.000 | <--- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 0 | -- | | | |
| #6 Oil fired boiler | -- | -- | 21,278 | -- | | | |
| Micronized coal refit | 1 | 12,176 | 13,460 | 1.743 | 6.0 | 14,970 | 1.567 |
| Slagging burner refit | 1 | 12,176 | 14,871 | 1.577 | 8.9 | 17,251 | 1.360 |
| Modular FBC refit | 1 | 12,330 | 15,241 | 1.539 | 9.8 | 17,927 | 1.308 |
| Stoker firing refit | 1 | 12,713 | 15,001 | 1.564 | 7.9 | 16,779 | 1.398 |
| Coal/water slurry | 1 | 12,988 | 17,284 | 1.357 | 10.5 | 18,780 | 1.249 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | 1 | 14,238 | 16,509 | 1.421 | 10.8 | 18,815 | 1.247 |
| Packaged shell stoker | 1 | 12,713 | 15,381 | 1.525 | 8.8 | 17,394 | 1.349 |
| Packaged shell FBC | 1 | 12,817 | 14,937 | 1.570 | 9.0 | 17,336 | 1.353 |
| Field erected stoker | 1 | 12,077 | 17,226 | 1.362 | 13.4 | 20,558 | 1.141 |
| Field erected FBC | 1 | 12,176 | 17,130 | 1.369 | 13.6 | 20,732 | 1.131 |
| Pulverized coal boiler | 1 | 11,879 | 17,647 | 1.329 | 14.7 | 21,455 | 1.093 |
| Circulating FBC | 1 | 12,026 | 17,848 | 1.314 | 15.4 | 22,031 | 1.065 |

MINOT AFB: 1 X 42 MBtu/hr. FUEL REAL ESCALATION - AEO 1987

Total steam output = 42.0 MBtu/hr
 Boiler capacity factor = .646
 Number of units for refit = 1
 Hydrated lime price (\$/ton) = 40.00
 Ash disposal price (\$/ton) = 10.00
 Electric price (cents/kWh) = 1.30
 Labor rate (k\$/yr) = 35.00
 Limestone price (\$/ton) = 20.00

FUEL PRICES
 Natural gas price (\$/MBtu) = 3.60
 #2 Oil price (\$/MBtu) = .00
 #6 Oil price (\$/MBtu) = 3.67

OPTIONS
 Soot blower multiplier = .0
 Tube bank mod multiplier = .0
 Bottom ash pit multiplier = 1.0
 SO2 control multiplier = .0

LIMESTONE/LIME
 Inert fraction = .05

COAL PROPERTIES

| | R.O.M. | Stoker |
|-----------------|----------|--------|
| Ash fraction | = .080 | .080 |
| Sulfur fraction | = .010 | .010 |
| HHV (Btu/lb) | = 12200. | 12300. |

FUEL PRICES
 R.O.M. coal (\$/MBtu) = 1.48
 Stoker coal (\$/MBtu) = 1.87
 Coal/H2O mix (\$/MBtu) = 3.00
 Coal/oil mix (\$/MBtu) = 3.50

Primary fuel is 3
 NATURAL GAS
 1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988
 Gen infla index (1987 to base yr) = 1.040
 Gas infla index (1988 to base yr) = 1.000
 Oil infla index (1988 to base yr) = 1.000
 Coal infla index (1988 to base yr) = 1.000
 Project start year = 1990
 Project life (yr) = 30
 Depreciation life (yr) = 15
 General inflation rate (I/yr) = 0
 Type of gas escalation = egas
 Type of oil escalation = eoil
 Type of coal escalation = ecoal
 Discount rate (I/yr) = 10
 Rate of return on invest (I/yr) = 17
 Amount of working capital (month) = 2
 Federal income tax rate (T) = 34
 Local prop tax (& insur) rate (T) = 2

| | | REAL ESCALATION RATE (I/yr) | | | |
|------|----------------------------|-----------------------------|-------|-------|----------|
| FUEL | TYPE OF FUEL ESCALATION | 1988 | 1990 | 1985 | 2000 AND |
| | | -1990 | -1995 | -2000 | BEYOND |
| Gas | egas | 2.28 | 4.70 | 5.49 | 2.75 |
| Oil | eoil | .17 | 4.16 | 5.55 | 2.77 |
| Coal | ecoal | 1.46 | 1.76 | 1.61 | .81 |

11:13 AM Jan 11, 1989

MINOT AVE: 1 X 42 MBtu/hr. FUEL REAL ESCALATION = AEO 1987

Total steam output = 42.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .646

Primary fuel = NATURAL GAS

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL \$K | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL \$K | MAINT O & M \$K | OTHER O & M \$K |
| Natural gas boiler | -- | .800 | 3.60 | .0 | 1069.5 | 150.3 | 427.6 |
| #2 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #6 Oil fired boiler | -- | .800 | 3.67 | .0 | 1090.3 | 150.3 | 427.6 |
| Micronized coal refit | 1 | .800 | 1.48 | 2319.2 | 439.7 | 345.8 | 557.4 |
| Slagging burner refit | 1 | .800 | 1.48 | 4026.2 | 439.7 | 345.8 | 557.4 |
| Modular FBC refit | 1 | .780 | 1.48 | 4631.1 | 445.3 | 329.1 | 553.4 |
| Stoker firing refit | 1 | .760 | 1.87 | 2779.8 | 584.8 | 329.1 | 551.6 |
| Coal/water slurry | 1 | .750 | 3.00 | 2068.4 | 950.7 | 329.1 | 481.3 |
| Coal/oil slurry | 1 | .780 | 3.50 | 1835.9 | 1066.5 | 282.1 | 457.5 |
| Low Btu gasifier refit | 1 | .679 | 1.87 | 3777.4 | 655.0 | 302.5 | 584.5 |
| Packaged shell stoker | 1 | .760 | 1.87 | 3240.1 | 584.8 | 329.1 | 551.6 |
| Packaged shell FBC | 1 | .760 | 1.48 | 4060.1 | 462.8 | 329.1 | 553.8 |
| Field erected stoker | 1 | .800 | 1.87 | 5845.8 | 555.6 | 327.1 | 549.2 |
| Field erected FBC | 1 | .800 | 1.48 | 6405.1 | 439.7 | 362.2 | 553.3 |
| Pulverized coal boiler | 1 | .820 | 1.48 | 6797.0 | 429.0 | 386.2 | 586.4 |
| Circulating FBC | 1 | .810 | 1.48 | 7556.0 | 434.3 | 327.1 | 593.2 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|---------------|------------------|--|---------------------|------------------------------------|--|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT \$K | BENEFIT/ COST RATIO | DISCOUNTED PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT \$K | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 12,044 | 1.000 | <--- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 0 | -- | | | |
| #6 Oil fired boiler | -- | -- | 17,487 | -- | | | |
| Micronized coal refit | 1 | 12,176 | 13,390 | 1.348 | 8.0 | 14,898 | 1.211 |
| Slagging burner refit | 1 | 12,176 | 14,801 | 1.219 | 12.6 | 17,179 | 1.050 |
| Modular FBC refit | 1 | 12,330 | 15,171 | 1.189 | 14.1 | 17,854 | 1.011 |
| Stoker firing refit | 1 | 12,713 | 14,908 | 1.210 | 11.5 | 16,683 | 1.082 |
| Coal/water slurry | 1 | 12,988 | 17,132 | 1.053 | 20.7 | 18,624 | .969 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | 1 | 14,238 | 16,405 | 1.100 | 17.8 | 18,707 | .955 |
| Packaged shell stoker | 1 | 12,713 | 15,258 | 1.180 | 13.1 | 17,298 | 1.043 |
| Packaged shell FBC | 1 | 12,817 | 14,863 | 1.214 | 12.8 | 17,260 | 1.045 |
| Field erected stoker | 1 | 12,077 | 17,137 | 1.053 | 23.1 | 20,467 | .882 |
| Field erected FBC | 1 | 12,176 | 17,060 | 1.058 | 22.9 | 20,660 | .873 |
| Pulverized coal boiler | 1 | 11,879 | 17,579 | 1.026 | 26.5 | 21,385 | .844 |
| Circulating FBC | 1 | 12,026 | 17,779 | 1.015 | 28.4 | 21,960 | .822 |

11:13 AM Jan 11, 1989

MINOT AFB: 1 X 42 MBtu/hr. FUEL REAL ESCALATION = ZERO

Total steam output = 42.0 MBtu/hr

Boiler capacity factor = .846

Number of units for refit = 1

Hydrated lime price (\$/ton) = 40.00

Ash disposal price (\$/ton) = 10.00

Electric price (cents/kWh) = 1.50

Labor rate (k\$/yr) = 35.00

Limestone price (\$/ton) = 20.00

FUEL PRICES

Natural gas price (\$/MBtu) = 3.60

#2 Oil price (\$/MBtu) = .00

#6 Oil price (\$/MBtu) = 3.67

OPTIONS

Soot blower multiplier = .0

Tube bank mod multiplier = .0

Bottom ash pit multiplier = 1.0

SO2 control multiplier = .0

LIMESTONE/LIME

Inert fraction = .05

COAL PROPERTIESR.O.M. Stoker

Ash fraction = .080 .080

Sulfur fraction = .010 .010

HHV (Btu/lb) = 12200. 12300.

FUEL PRICES

R.O.M. coal (\$/MBtu) = 1.48

Stoker coal (\$/MBtu) = 1.87

Coal/H2O mix (\$/MBtu) = 3.00

Coal/oil mix (\$/MBtu) = 3.50

Primary fuel is 3

NATURAL GAS

1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988

Gen infla index (1987 to base yr) = 1.040

Gas infla index (1988 to base yr) = 1.000

Oil infla index (1988 to base yr) = 1.000

Coal infla index (1988 to base yr) = 1.000

Project start year = 1990

Project life (yr) = 30

Depreciation life (yr) = 15

General inflation rate (I/yr) = 0

Type of gas escalation = zero

Type of oil escalation = zero

Type of coal escalation = zero

Discount rate (I/yr) = 10

Rate of return on invest (I/yr) = 17

Amount of working capital (month) = 2

Federal income tax rate (I) = 34

Local prop tax (& insur) rate (I) = 2

REAL ESCALATION RATE (I/yr)

| FUEL | TYPE OF FUEL ESCALATION | 1988 | 1990 | 1995 | 2000 AND BEYOND |
|------|----------------------------|-------|-------|-------|--------------------|
| | | -1990 | -1995 | -2000 | |
| Gas | zero | 0 | 0 | 0 | 0 |
| Oil | zero | 0 | 0 | 0 | 0 |
| Coal | zero | 0 | 0 | 0 | 0 |

11:23 AM Jan 11, 1989

MINOT AFB: 1 X 42 MBtu/hr. FUEL REAL ESCALATION = ZERO

Total steam output = 42.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .646

Primary fuel = NATURAL GAS

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | OTHER O & M k\$ |
| Natural gas boiler | -- | .800 | 3.60 | .0 | 1060.5 | 150.3 | 427.6 |
| #2 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #6 Oil fired boiler | -- | .800 | 3.67 | .0 | 1090.3 | 150.3 | 427.6 |
| Micronized coal refit | 1 | .800 | 1.48 | 2319.2 | 439.7 | 345.8 | 557.4 |
| Slagging burner refit | 1 | .800 | 1.48 | 4026.2 | 439.7 | 345.8 | 557.4 |
| Modular FBC refit | 1 | .790 | 1.48 | 4631.1 | 445.3 | 329.1 | 553.4 |
| Stoker firing refit | 1 | .780 | 1.87 | 2779.8 | 584.8 | 329.1 | 551.6 |
| Coal/water slurry | 1 | .750 | 3.00 | 2068.4 | 950.7 | 329.1 | 481.3 |
| Coal/oil slurry | 1 | .780 | 3.50 | 1835.9 | 1066.5 | 262.1 | 457.5 |
| Low Btu gasifier refit | 1 | .870 | 1.87 | 3777.4 | 655.0 | 303.5 | 584.5 |
| Packaged shell stoker | 1 | .760 | 1.87 | 3240.1 | 584.8 | 320.1 | 551.6 |
| Packaged shell FBC | 1 | .760 | 1.48 | 4060.1 | 462.8 | 329.1 | 553.8 |
| Field erected stoker | 1 | .800 | 1.67 | 5845.8 | 555.6 | 327.1 | 549.2 |
| Field erected FBC | 1 | .800 | 1.48 | 6405.1 | 439.7 | 382.2 | 553.3 |
| Pulverized coal boiler | 1 | .820 | 1.48 | 6797.0 | 429.0 | 386.2 | 586.4 |
| Circulating FBC | 1 | .810 | 1.48 | 7556.0 | 434.3 | 327.1 | 593.2 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|---------------|------------------|--|---------------------|------------------------------------|--|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO | DISCOUNTED PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 13,008 | 1.000 | <--- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 0 | -- | | | |
| #6 Oil fired boiler | -- | -- | 13,170 | -- | | | |
| Micronized coal refit | 1 | 12,176 | 12,777 | 1.018 | 19.8 | 14,268 | .912 |
| Slagging burner refit | 1 | 12,176 | 14,188 | .917 | >31 | 16,549 | .786 |
| Modular FBC refit | 1 | 12,330 | 14,551 | .894 | >31 | 17,216 | .756 |
| Stoker firing refit | 1 | 12,713 | 14,093 | .923 | >31 | 15,845 | .821 |
| Coal/water slurry | 1 | 12,988 | 15,808 | .823 | >31 | 17,263 | .754 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | 1 | 14,238 | 15,492 | .840 | >31 | 17,769 | .732 |
| Packaged shell stoker | 1 | 12,713 | 14,474 | .899 | >31 | 16,461 | .790 |
| Packaged shell FBC | 1 | 12,817 | 14,219 | .915 | >31 | 16,597 | .784 |
| Field erected stoker | 1 | 12,077 | 16,363 | .795 | >31 | 19,672 | .661 |
| Field erected FBC | 1 | 12,176 | 16,447 | .791 | >31 | 20,030 | .649 |
| Pulverized coal boiler | 1 | 11,879 | 16,981 | .766 | >31 | 20,770 | .626 |
| Circulating FBC | 1 | 12,026 | 17,174 | .757 | >31 | 21,338 | .610 |

11:23 AM Jan 11, 1989

PEASE AFB: SAC

1. BACKGROUND

Pease AFB is located near Portsmouth, New Hampshire. The steam plant consists of two 110-MBtu/h water-tube units firing natural gas as the primary fuel and No. 6 oil as the secondary fuel. A refuse-derived fuel has also been used in these boilers. These boilers were originally designed for residual fuel oil combustion. Average annual fuel use was about 42 MBtu/h for FY 1986. Refuse-derived fuel was about 45% of the total.

2. HEATING PLANT UNITS

Heating Plant No. 124:

2 x 110 MBtu/h, Combustion Engineering, 1955

3. IDEAL CAPACITY FACTOR ANALYSIS

The ideal capacity factors listed below were calculated from monthly fuel-use data for plant No. 124.

| <u>Fuel input (MBtu/h)</u> | <u>FY 1986 ideal capacity factor</u> |
|------------------------------------|--|
| 40 | 0.68 |
| 50 | 0.64 |
| 70 | 0.56 |
| 90 | 0.47 |
| 110 | 0.39 |

4. ENERGY PRICES

FY 1986 Price Data:

Electricity = \$15.5/MBtu = 5.3¢/kWh

Distillate = \$5.91/MBtu

Residual = \$4.54/MBtu

Natural gas = \$3.8/MBtu

5. COAL PROPERTIES AND PRICES

| | Stoker | ROM |
|-------------------------------------|------------|------------|
| Origin | Slago, Pa. | Slago, Pa. |
| HHV, Btu/lb | 13,000 | 12,800 |
| % Ash | 7-9 | 8-10 |
| % Sulfur | 1.8-2.2 | 1.8-2.2 |
| % Nitrogen | 1.32 | 1.30 |
| Ash-softening temperature, °F | 2500 | 2300 |
| Swelling index | 6-8 | 6-8 |
| Top size, in. | 1 5/8 | 2 |
| Bottom size, in. | 1/2 | 0 |
| Fines, % | 5 | |
| Grindability index | 50-55 | 50-55 |
| Cost at mine, \$/ton | 40 | 26.50 |
| Delivered cost, \$/ton | 66.60 | 53.10 |
| Energy cost, \$/10 ⁶ Btu | 2.56 | 2.07 |

The coal prices quoted above assume rail delivery to Pease AFB. The base is currently removing its rail connection because it crosses a major highway. If coal has to be delivered by truck, delivered costs could be higher by as much as \$0.50/MBtu.

6. ENVIRONMENTAL REGULATIONS

6.1 Air Pollution Emission Limits for New Sources

SO₂. No emission limits for boilers <100 MBtu/h; for boilers >100 MBtu/h: FBC - 90% reduction to meet limit of 1.2 lb/MBtu; emerging technology - 50% reduction to meet limit of 0.6 lb/MBtu.

No_x. No emission limits for boilers <100 MBtu/h; for boilers >100 MBtu/h: spreader stoker and FBC - 0.6 lb/MBtu; pulverized coal - 0.7 lb/MBtu.

Particulates. For boilers >100 MBtu/h: 0.05 lb/MBtu.

6.2 Coal-Pile Runoff

Limit: Total suspended solids - 50 mg/L.

6.3 Ash Disposal

Ashes are classified as nonhazardous industrial solid waste and may be disposed of in any approved sanitary landfill.

7. OTHER CONSIDERATIONS

None

8. COAL-CONVERSION PROJECT OUTLOOK

Replacement/refit of one boiler may be attractive. It is estimated that the overall capacity factor for conversion of one 110-MBtu/h unit to coal, but derated to 75 MBtu/h output (~94 MBtu/h fuel input) to avoid environmental regulations, would be roughly 41% assuming 90% availability.

8.1 Effect of Environmental Regulations on Selection of Combustion Technologies

SO₂ and NO_x. Any of the combustion technologies being considered could be employed without requiring any measures for NO_x or SO₂ reduction since the proposed conversion project is smaller than 100 MBtu/h.

Particulates. Bag filters or electrostatic precipitators would be required to comply with the particulate emission limits.

8.2 Physical Space and Aesthetics

Heating Plant. The existing boiler plant was originally designed for No. 6 oil, so return to stoker is not possible. There is space available for installing coal combustion equipment at the existing boiler or for construction of a new boiler at another site on base.

Coal-Handling Equipment. There is space available for installing coal-handling equipment at the existing boiler.

Coal Pile. There is space available for a coal pile at the existing boiler plant or at a new site on base.

8.3 Technical Risk of Combustion Technologies

The existing boilers are designed for No. 6 oil-firing and therefore are not suitable for conversion to stoker-firing, but they could be converted to coal-water mixture or micronized coal-firing. Since the peak winter fuel use is about 85 MBtu/h, one of the 110-MBtu/h boilers could be derated to 68% capacity and meet the peak load. This would make the technical risk low for either coal-water-mixture or micronized coal.

9. COGENERATION PROJECT OUTLOOK

The prospects for a coal-fired cogeneration system appear to be marginal. The minimum average monthly electrical load is fairly low, 3.2 MWe, and the price of electricity is only moderately high, 5.3¢/kWh. Based on the FY 1986 energy-use data, a cogeneration plant with a boiler rating of 64 MBtu/h output and a 3-MWe turbine-generator would have an electrical power capacity factor of 90% and

a peak thermal output of 40 MBtu/h, with a thermal energy capacity factor of about 65% if used as a baseload heating plant. A water-tube boiler with a steam rating of 1200 psia and 900°F would be the most suitable boiler for this cogeneration system.

10. INPUT AND LCC SUMMARY SPREADSHEETS

PLANT AREA: 1 X 75 MW/hr. ECONOMIC PARAMETERS - NOMINAL VALUES

Total steam output = 75.0 MW/hr

Boiler capacity factor = .407

Number of units for refit = 1

Hydrated lime price (\$/ton) = 40.00

Ash disposal price (\$/ton) = 10.00

Electric price (cents/kwh) = 3.30

Labor rate (k\$/yr) = 35.00

Limestone price (\$/ton) = 20.00

FUEL PRICES

Natural gas price (\$/MBtu) = 3.80

#2 Oil price (\$/MBtu) = .00

#6 Oil price (\$/MBtu) = 3.57

OPTIONS

Soot blower multiplier = .0

Tube bank mod multiplier = .0

Bottom ash pit multiplier = 1.0

SO2 control multiplier = .0

LIMESTONE/LIME

Inert fraction = .05

COAL PROPERTIESR.O.M. Stoker

Ash fraction = .090 .080

Sulfur fraction = .020 .020

HHV (Btu/lb) = 12800. 13000.

FUEL PRICES

R.O.M. coal (\$/MBtu) = 2.07

Stoker coal (\$/MBtu) = 2.36

Coal/H2O mix (\$/MBtu) = 3.00

Coal/oil mix (\$/MBtu) = 3.50

Primary fuel is 3

NATURAL GAS

1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988

Gen infla index (1997 to base yr) = 1.040

Gas infla index (1988 to base yr) = 1.000

Oil infla index (1988 to base yr) = 1.000

Coal infla index (1988 to base yr) = 1.000

Project start year = 1990

Project life (yr) = 30

Depreciation life (yr) = 15

General inflation rate (1/yr) = 0

Type of gas escalation = egas

Type of oil escalation = eoil

Type of coal escalation = ecoal

Discount rate (1/yr) = 10

Rate of return on invest (1/yr) = 17

Amount of working capital (month) = 2

Federal income tax rate (1) = 34

Local prop tax (& insur) rate (1) = 2

| | | REAL ESCALATION RATE (1/yr) | | | |
|------|--------------|-----------------------------|-------|-------|----------|
| | TYPE OF FUEL | 1988 | 1990 | 1995 | 2000 AND |
| FUEL | ESCALATION | -1980 | -1995 | -2000 | BEYOND |
| Gas | egas | 3.89 | 8.87 | 5.77 | 5.77 |
| Oil | eoil | 4.86 | 7.87 | 4.16 | 4.16 |
| Coal | ecoal | 1.16 | 2.31 | 1.19 | 1.19 |

4:20 PM Oct 21, 1988

TABLE A-1: 1 X 75 Mtu/hr. ECONOMIC PARAMETERS - NOMINAL VALUES

Total steam output = 75.0 Mtu/hr

Cost base year = 1988

Boiler capacity factor = .407

Primary fuel = NATURAL GAS

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MTU | TOTAL CAPITAL \$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|-------------------|------------------|--------------|--------------|----------------|
| | | | | | FUEL \$ | MAINT & M \$ | OTHER O & M \$ |
| Natural gas boiler | -- | .800 | 3.80 | .0 | 1270.1 | 208.8 | 322.8 |
| #2 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #6 Oil fired boiler | -- | .800 | 3.67 | .0 | 1228.7 | 208.8 | 322.8 |
| Micronized coal refit | 1 | .800 | 2.07 | 3177.7 | 691.9 | 428.6 | 696.3 |
| Slagging burner refit | 1 | .800 | 2.07 | 3568.5 | 691.9 | 428.6 | 696.3 |
| Modular FBC refit | 1 | .780 | 2.07 | 6413.8 | 700.7 | 403.5 | 880.0 |
| Stoker firing refit | 1 | .760 | 2.58 | 3759.5 | 900.7 | 403.5 | 870.4 |
| Coal/water slurry | 1 | .750 | 3.00 | 2873.4 | 1069.8 | 403.5 | 593.8 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2573.8 | 1199.8 | 322.9 | 566.0 |
| Low Btu gasifier refit | 2 | .678 | 2.56 | 6532.0 | 1008.8 | 374.0 | 931.3 |
| Packaged shell stoker | 2 | .760 | 2.56 | 5631.0 | 900.7 | 403.5 | 766.7 |
| Packaged shell FBC | 2 | .760 | 2.07 | 7033.5 | 728.3 | 403.5 | 776.8 |
| Field erected stoker | 1 | .800 | 2.58 | 8326.1 | 855.7 | 403.0 | 860.5 |
| Field erected FBC | 1 | .800 | 2.07 | 9182.0 | 691.9 | 470.9 | 679.8 |
| Pulverized coal boiler | 1 | .820 | 2.07 | 9710.9 | 675.0 | 475.9 | 709.6 |
| Circulating FBC | 1 | .810 | 2.07 | 11087.6 | 683.4 | 403.0 | 735.1 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|--|------------------|---|---------------------|------------------------------------|---|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT \$ | BENEFIT/ COST RATIO | PAYBACK PERIOD, YR | LIFE CYCLE COST, DISCOUNTED AS SPENT \$ | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 28,224 | 1.000 | ---- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 0 | -- | | | |
| #6 Oil fired boiler | -- | -- | 24,600 | -- | | | |
| Micronized coal refit | 1 | 13,057 | 18,330 | 1.540 | 7.9 | 20,395 | 1.384 |
| Slagging burner refit | 1 | 13,057 | 20,306 | 1.380 | 12.0 | 23,591 | 1.196 |
| Modular FBC refit | 1 | 13,222 | 20,770 | 1.359 | 13.1 | 24,479 | 1.153 |
| Stoker firing refit | Not applicable because existing boiler was designed for #6 oil | | | | | | |
| Coal/water slurry | 1 | 13,927 | 20,621 | 1.369 | 10.4 | 27,605 | 1.249 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | 2 | 15,156 | 25,423 | 1.110 | 22.3 | 29,322 | .963 |
| Packaged shell stoker | 2 | 13,532 | 22,667 | 1.245 | 15.8 | 26,050 | 1.083 |
| Packaged shell FBC | 2 | 13,744 | 22,294 | 1.266 | 15.8 | 26,349 | 1.071 |
| Field erected stoker | 1 | 12,856 | 23,625 | 1.195 | 18.6 | 28,346 | .996 |
| Field erected FBC | 1 | 13,057 | 23,560 | 1.198 | 18.8 | 28,696 | .984 |
| Pulverized coal boiler | 1 | 12,738 | 24,115 | 1.170 | 20.0 | 29,524 | .956 |
| Circulating FBC | 1 | 12,895 | 24,887 | 1.134 | 22.0 | 30,987 | .911 |

4:20 PM Oct 21, 1988

PLATE AFR: 1 X 75 MBtu/hr. FUEL REAL ESCALATION = AYO 1987

Total steam output = 75.0 MBtu/hr

Roller capacity factor = .407

Number of units for refit = 1

Hydrated lime price (\$/ton) = 40.00

Ash disposal price (\$/ton) = 10.00

Electric price (cents/kWh) = 5.30

Labor rate (\$/yr) = 35.00

Limestone price (\$/ton) = 20.00

FUEL PRICES

Natural gas price (\$/MBtu) = 3.80

#2 Oil price (\$/MBtu) = .00

#6 Oil price (\$/MBtu) = 2.67

OPTIONS

Soot blower multiplier = .0

Tube bank mod multiplier = .0

Bottom ash pit multiplier = 1.0

SO2 control multiplier = .0

LIMESTONE/LIME

Inert fraction = .05

COAL PROPERTIES

R.O.M. Stoker

Ash fraction = .000 .080

Sulfur fraction = .020 .020

HHV (Btu/lb) = 12800. 13000.

FUEL PRICES

R.O.M. coal (\$/MBtu) = 2.07

Stoker coal (\$/MBtu) = 2.58

Coal/H2O mix (\$/MBtu) = 3.00

Coal/oil mix (\$/MBtu) = 3.50

Primary fuel is 3

NATURAL GAS

1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988

Gen infla index (1987 to base yr) = 1.040

Gas infla index (1988 to base yr) = 1.000

Oil infla index (1988 to base yr) = 1.000

Coal infla index (1988 to base yr) = 1.000

Project start year = 1990

Project life (yr) = 30

Depreciation life (yr) = 15

General inflation rate (I/yr) = 0

Type of gas escalation = egas

Type of oil escalation = eoil

Type of coal escalation = ecoal

Discount rate (I/yr) = 10

Rate of return on invest (I/yr) = 17

Amount of working capital (month) = 2

Federal income tax rate (I) = 34

Local prop tax (& insur) rate (I) = 2

| | | REAL ESCALATION RATE (I/yr) | | | |
|------|----------------------------|-----------------------------|-------|-------|--------------------|
| FUEL | TYPE OF FUEL ESCALATION | 1988 | 1990 | 1995 | 2000 AND BEYOND |
| | | -1990 | -1995 | -2000 | |
| Gas | egas | 2.28 | 4.70 | 5.40 | 2.75 |
| Oil | eoil | .17 | 4.16 | 5.55 | 2.77 |
| Coal | ecoal | 1.46 | 1.76 | 1.61 | .81 |

4:25 PM Oct 21, 1988

PLEASE AVE: 1 X 75 MBtu/hr. FUEL REAL ESCALATION = AEO 1987

Total steam output = 75.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .407

Primary fuel = NATURAL GAS

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | OTHER O & M k\$ |
| Natural gas boiler | -- | .800 | 3.80 | .0 | 1270.1 | 206.8 | 522.8 |
| #2 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #6 Oil fired boiler | -- | .800 | 3.67 | .0 | 1226.7 | 206.8 | 522.3 |
| Micronized coal refit | 1 | .800 | 2.07 | 3177.7 | 691.9 | 426.6 | 696.3 |
| Slagging burner refit | 1 | .800 | 2.07 | 5568.5 | 691.9 | 426.6 | 690.3 |
| Modular FBC refit | 1 | .790 | 2.07 | 6413.8 | 700.7 | 405.5 | 680.0 |
| Stoker firing refit | 1 | .760 | 2.56 | 3759.5 | 900.7 | 405.5 | 670.4 |
| Coal/water slurry | 1 | .750 | 3.00 | 2875.4 | 1069.6 | 405.5 | 593.8 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2573.8 | 1199.9 | 322.9 | 566.9 |
| Low Btu gasifier refit | 2 | .679 | 2.56 | 6532.0 | 1006.8 | 374.0 | 931.3 |
| Packaged shell stoker | 2 | .760 | 2.56 | 5631.0 | 900.7 | 405.5 | 766.7 |
| Packaged shell FBC | 2 | .760 | 2.07 | 7033.5 | 728.3 | 405.5 | 776.8 |
| Field erected stoker | 1 | .800 | 2.56 | 8326.1 | 855.7 | 405.0 | 660.5 |
| Field erected FBC | 1 | .800 | 2.07 | 9182.0 | 691.9 | 470.9 | 679.8 |
| Pulverized coal boiler | 1 | .820 | 2.07 | 9710.9 | 675.0 | 475.9 | 709.6 |
| Circulating FBC | 1 | .810 | 2.07 | 11067.6 | 683.4 | 403.0 | 736.1 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|--|------------------|--|---------------------|------------------------------------|--|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO | DISCOUNTED PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 21,797 | 1.000 | <--- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 0 | -- | | | |
| #6 Oil fired boiler | -- | -- | 20,335 | -- | | | |
| Micronized coal refit | 1 | 13,057 | 18,220 | 1.196 | 11.7 | 20,282 | 1.075 |
| Slagging burner refit | 1 | 13,057 | 20,165 | 1.079 | 19.9 | 23,477 | .928 |
| Modular FBC refit | 1 | 13,222 | 20,659 | 1.055 | 22.6 | 24,365 | .895 |
| Stoker firing refit | Not applicable because existing boiler was designed for #6 oil | | | | | | |
| Coal/water slurry | 1 | 13,927 | 20,451 | 1.066 | 19.4 | 22,430 | .972 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | 2 | 15,156 | 25,262 | .863 | >31 | 29,157 | .746 |
| Packaged shell stoker | 2 | 13,532 | 22,524 | .868 | >31 | 25,803 | .842 |
| Packaged shell FBC | 2 | 13,744 | 22,179 | .983 | >31 | 26,230 | .831 |
| Field erected stoker | 1 | 12,856 | 23,489 | .928 | >31 | 28,206 | .773 |
| Field erected FBC | 1 | 13,057 | 23,450 | .930 | >31 | 28,582 | .763 |
| Pulverized coal boiler | 1 | 12,738 | 24,008 | .908 | >31 | 29,413 | .741 |
| Circulating FBC | 1 | 12,895 | 24,778 | .880 | >31 | 30,875 | .706 |

4:25 PM Oct 21, 1988

PHASE AFB: 1 X 75 MBtu/hr. FUEL REAL ESCALATION = ZERO

Total steam output = 75.0 MBtu/hr
 Boiler capacity factor = .407
 Number of units for refit = 1
 Hydrated lime price (\$/ton) = 40.00
 Ash disposal price (\$/ton) = 10.00
 Electric price (cents/kWh) = 3.30
 Labor rate (k\$/yr) = 35.00
 Limestone price (\$/ton) = 20.00

FUEL PRICES
 Natural gas price (\$/MBtu) = 3.80
 #2 Oil price (\$/MBtu) = .00
 #6 Oil price (\$/MBtu) = 3.67

COAL PROPERTIES
 R.O.M. Stoker
 Ash fraction = .090 .080
 Sulfur fraction = .020 .020
 HHV (Btu/lb) = 12800. 13000.

FUEL PRICES
 R.O.M. coal (\$/MBtu) = 2.07
 Stoker coal (\$/MBtu) = 2.56
 Coal/H₂O mix (\$/MBtu) = 3.00
 Coal/oil mix (\$/MBtu) = 3.50

OPTIONS
 Soot blower multiplier = .0
 Tube bank mod multiplier = .0
 Bottom ash pit multiplier = 1.0
 SO₂ control multiplier = .0

LIMESTONE/LIME
 Inert fraction = .05

ECONOMIC PARAMETERS
 Inflation & discounting base year = 1988
 Gen infla index (1987 to base yr) = 1.040
 Gas infla index (1988 to base yr) = 1.000
 Oil infla index (1988 to base yr) = 1.000
 Coal infla index (1988 to base yr) = 1.000
 Project start year = 1990
 Project life (yr) = 30
 Depreciation life (yr) = 15
 General inflation rate (I/yr) = 0
 Type of gas escalation = zero
 Type of oil escalation = zero
 Type of coal escalation = zero
 Discount rate (I/yr) = 10
 Rate of return on invest (I/yr) = 17
 Amount of working capital (month) = 2
 Federal income tax rate (I) = 34
 Local prop tax (& insur) rate (I) = 2

Primary fuel is 3
NATURAL GAS
 1-#6 Oil, 2-#2 Oil, 3-NG

| FUEL | TYPE OF FUEL ESCALATION | REAL ESCALATION RATE (I/yr) | | | |
|------|----------------------------|-----------------------------|---------------|---------------|--------------------|
| | | 1988 -1990 | 1990 -1995 | 1995 -2000 | 2000 AND BEYOND |
| Gas | zero | 0 | 0 | 0 | 0 |
| Oil | zero | 0 | 0 | 0 | 0 |
| Coal | zero | 0 | 0 | 0 | 0 |

4:28 PM Oct 21, 1988

PEACE AFB: 1 X 75 Mbtu/hr. FUEL REAL ESCALATION = ZERO

Total steam output = 75.0 Mbtu/hr

Cost base year = 1988

Boiler capacity factor = .407

Primary fuel = NATURAL GAS

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/Mbtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | OTHER O & M k\$ |
| Natural gas boiler | -- | .800 | 3.80 | .0 | 1270.1 | 206.8 | 522.8 |
| #2 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #6 Oil fired boiler | -- | .800 | 3.67 | .0 | 1226.7 | 206.8 | 522.8 |
| Micronized coal refit | 1 | .800 | 2.07 | 3177.7 | 691.8 | 426.6 | 695.3 |
| Slagging burner refit | 1 | .800 | 2.07 | 5568.5 | 691.8 | 426.6 | 695.3 |
| Modular FBC refit | 1 | .790 | 2.07 | 6413.8 | 700.7 | 405.5 | 680.0 |
| Stoker firing refit | 1 | .760 | 2.56 | 3759.5 | 900.7 | 405.5 | 670.4 |
| Coal/water slurry | 1 | .750 | 3.00 | 2875.4 | 1069.6 | 405.5 | 593.8 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2573.8 | 1199.9 | 322.9 | 566.9 |
| Low Btu gasifier refit | 2 | .870 | 2.56 | 6532.0 | 1008.8 | 374.0 | 931.3 |
| Packaged shell stoker | 2 | .760 | 2.56 | 5631.5 | 900.7 | 405.5 | 766.7 |
| Packaged shell FBC | 2 | .760 | 2.07 | 7033.5 | 728.3 | 405.5 | 776.8 |
| Field erected stoker | 1 | .800 | 2.56 | 8326.1 | 855.7 | 403.0 | 660.5 |
| Field erected FBC | 1 | .800 | 2.07 | 9182.0 | 691.8 | 470.9 | 670.8 |
| Pulverized coal boiler | 1 | .820 | 2.07 | 9710.9 | 675.0 | 475.9 | 709.6 |
| Circulating FBC | 1 | .910 | 2.07 | 11087.6 | 683.4 | 403.0 | 736.1 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|--|------------------|--|---------------------|------------------------------------|--|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO | DISCOUNTED PAYBACK PERIOD, yr | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 15,817 | 1.000 | <--- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 0 | -- | | | |
| #6 Oil fired boiler | -- | -- | 15,479 | -- | | | |
| Micronized coal refit | 1 | 13,057 | 17,256 | .917 | >31 | 19,291 | .820 |
| Slagging burner refit | 1 | 13,057 | 19,232 | .822 | >31 | 22,486 | .703 |
| Modular FBC refit | 1 | 13,222 | 19,683 | .804 | >31 | 23,361 | .677 |
| Stoker firing refit | Not applicable because existing boiler was designed for #6 oil | | | | | | |
| Coal/water slurry | 1 | 13,927 | 18,962 | .834 | >31 | 20,898 | .757 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | 2 | 15,156 | 23,857 | .663 | >31 | 27,712 | .571 |
| Packaged shell stoker | 2 | 13,532 | 21,270 | .744 | >31 | 24,612 | .643 |
| Packaged shell FBC | 2 | 13,744 | 21,164 | .747 | >31 | 25,186 | .628 |
| Field erected stoker | 1 | 12,856 | 22,297 | .709 | >31 | 26,980 | .586 |
| Field erected FBC | 1 | 13,057 | 22,486 | .703 | >31 | 27,591 | .573 |
| Pulverized coal boiler | 1 | 12,738 | 23,068 | .686 | >31 | 28,447 | .556 |
| Circulating FBC | 1 | 12,895 | 23,826 | .664 | >31 | 29,897 | .529 |

4:28 PM Oct 21, 1988

PLATTSBURGH AFB: SAC

1. BACKGROUND

Plattsburgh AFB is located near Plattsburgh, New York. The main boiler plant (building 2658) has 6 x 50-MBtu/h boilers firing the design fuel, No. 6 oil. The boiler plant produces pressurized hot water with temperatures up to about 400°F. The yearly average fuel use is roughly 83 MBtu/h.

2. HEATING PLANT UNITS

Heating Plant No. 2658:

4 x 50 MBtu/h, International Boiler Works, 1955
2 x 50 MBtu/h, Combustion Engineering, 1957

3. IDEAL CAPACITY FACTOR ANALYSIS

The ideal capacity factors listed below were calculated from monthly fuel-use data for plant No. 2658.

| Fuel input (MBtu/h) | FY 1987 ideal capacity factor | FY 1988 ideal capacity factor |
|---------------------------|--|--|
| 40 | 0.96 | 0.95 |
| 50 | 0.99 | 0.90 |
| 70 | 0.83 | 0.81 |
| 90 | 0.76 | 0.75 |
| 100 | 0.73 | 0.72 |

4. ENERGY PRICES

FY 1986 Price Data:

| | Year average | End of year |
|------------|-------------------------|-------------|
| Distillate | \$5.90/MBtu | Same |
| Residual | \$5.08/MBtu | Same |
| Electric | \$17.3/MBtu = 5.91¢/kWh | 6.3¢/kWh |

C. H. Guernsey and Co. Survey:

The most recent costs from the C. H. Guernsey and Co. survey agree with the FY 1986 costs.

5. COAL PROPERTIES AND PRICES

| | Stoker | ROM |
|-------------------------------------|------------|------------|
| Origin | Slago, Pa. | Slago, Pa. |
| HHV, Btu/lb | 13,000 | 12,800 |
| % Ash | 7-9 | 8-10 |
| % Sulfur | 1.8-2.2 | 1.8-2.2 |
| % Nitrogen | 1.32 | 1.30 |
| Ash-softening temperature, °F | 2500 | 2300 |
| Swelling index | 6-8 | 6-8 |
| Top size, in. | 1 5/8 | 2 |
| Bottom size, in. | 1/2 | 0 |
| Fines, % | 5 | |
| Grindability index | 50-55 | 50-55 |
| Cost at mine, \$/ton | 40 | 26.50 |
| Delivered cost, \$/ton | 64.00 | 50.50 |
| Energy cost, \$/10 ⁶ Btu | 2.46 | 1.97 |

6. ENVIRONMENTAL REGULATIONS

6.1 Air Pollution Emission Limits for New Sources

SO₂. No emission limits for boilers <100 MBtu/h; for boilers >100 MBtu/h: FBC - 90% reduction to meet limit of 1.2 lb/MBtu; emerging technology - 50% reduction to meet limit of 0.6 lb/MBtu.

NO_x. No emission limits for boilers <100 MBtu/h; for boilers >100 MBtu/h: spreader stoker and FBC - 0.6 lb/MBtu; pulverized coal - 0.7 lb/MBtu.

Particulates. For boilers >100 MBtu/h: 0.05 lb/MBtu.

6.2 Coal-File Runoff

Limit: Total suspended solids - 50 mg/L.

6.3 Ash Disposal

Ashes are classified as nonhazardous solid waste and may be disposed of in any approved sanitary landfill.

7. OTHER CONSIDERATIONS

None

8. COAL CONVERSION PROJECT OUTLOOK

Based on load data, a refit/replacement project would probably involve one 50-MBtu/h output (~63 MBtu/h fuel input) boiler. The overall capacity factor is estimated to be about 76%, assuming 90% equipment availability.

8.1 Effect of Environmental Regulations on Selection of Combustion Technologies

SO₂ and NO_x. Any of the combustion technologies being considered could be employed without requiring any measures for NO_x or SO₂ reduction since the proposed conversion project is smaller than 100 MBtu/h.

Particulates. Bag filters or electrostatic precipitators would be required to comply with the particulate emission limits.

8.2 Physical Space and Aesthetics

Heating Plant. The existing boiler plant was originally designed for No. 6 oil, so return to stoker is not possible. There is space available for installing coal-combustion equipment at the existing boiler or for construction of a new boiler at another site on base.

Coal-Handling Equipment. There is space available for installing coal-handling equipment at the existing boiler.

Coal Pile. There is space available for a coal pile at the existing boiler plant or at a new site on base.

8.3 Technical Risk of Combustion Technologies

The existing boilers are designed for No. 6 oil-firing and therefore are not suitable for conversion to stoker-firing. The least technical risk would be for installation of a new stoker boiler. The refit technologies would have greater technical risks because of lack of operating experience, and all of them would be of the same order since no SO₂ removal is necessary.

9. COGENERATION PROJECT OUTLOOK

The prospects for a coal-fired cogeneration system appear to be interesting. The minimum average monthly electrical load is fairly low, 3.2 MWe, but the price of electricity is moderately high, 6.3¢/kWh. Based on the FY 1986 energy-use data, a cogeneration plant with a boiler rating of 64-MBtu/h output and a 3-MWe turbine-generator would have an electrical power capacity factor of 90% and a peak thermal output of 40 MBtu/h, with a thermal energy capacity factor of about 65% if used as a baseload heating plant. A water-tube boiler with a steam rating of 1200 psia and 900°F would be the most suitable boiler for this cogeneration system.

10. INPUT AND LCC SUMMARY SPREADSHEETS

PLATTSBURGH AFB: 1 X 50 MBtu/hr. ECONOMIC PARAMETERS ~ NOMINAL VALUES

Total steam output = 50.0 MBtu/hr

Boiler capacity factor = .764

Number of units for refit = 1

Hydrated lime price (\$/ton) = 40.00

Ash disposal price (\$/ton) = 10.00

Electric price (cents/kwh) = 8.30

Labor rate (\$/yr) = 35.00

Limestone price (\$/ton) = 20.00

FUEL PRICES

Natural gas price (\$/MBtu) = .00

#2 Oil price (\$/MBtu) = .00

#6 Oil price (\$/MBtu) = 3.67

OPTIONS

Soot blower multiplier = .0

Tube bank mod multiplier = 1.0

Bottom ash pit multiplier = 1.0

SO2 control multiplier = .0

LIMESTONE/LIME

Inert fraction = .05

COAL PROPERTIES**R.O.M. Stoker**

Ash fraction = .090 .080

Sulfur fraction = .020 .020

HHV (Btu/lb) = 12800. 13000.

FUEL PRICES

R.O.M. coal (\$/MBtu) = 1.87

Stoker coal (\$/MBtu) = 2.46

Coal/H2O mix (\$/MBtu) = 3.00

Coal/oil mix (\$/MBtu) = 3.50

Primary fuel is 1

#6 FUEL OIL

1-#6 Oil, 2-#2 Oil, 3-G

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988

Gen infla index (1987 to base yr) = 1.040

Gas infla index (1988 to base yr) = 1.000

Oil infla index (1988 to base yr) = 1.000

Coal infla index (1988 to base yr) = 1.000

Project start year = 1990

Project life (yr) = 30

Depreciation life (yr) = 15

General inflation rate (I/yr) = 0

Type of gas escalation = egas

Type of oil escalation = eoil

Type of coal escalation = ecoal

Discount rate (I/yr) = 10

Rate of return on invest (I/yr) = 17

Amount of working capital (month) = 2

Federal income tax rate (I) = 34

Local prop tax (& insur) rate (I) = 2

| FUEL | TYPE OF FUEL ESCALATION | REAL ESCALATION RATE (I/yr) | | | |
|------|----------------------------|-----------------------------|---------------|---------------|--------------------|
| | | 1988 -1990 | 1990 -1995 | 1995 -2000 | 2000 AND BEYOND |
| Gas | egas | 3.89 | 6.87 | 5.77 | 5.77 |
| Oil | eoil | 4.86 | 7.87 | 4.16 | 4.16 |
| Coal | ecoal | 1.16 | 2.31 | 1.19 | 1.19 |

2:19 PM Jan 4, 1989

PLATTSBURGH AFB: 1 X 50 MBtu/hr. ECONOMIC PARAMETERS - NOMINAL VALUES

Total steam output = 50.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .764

Primary fuel = #6 FUEL OIL

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL \$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|------------------|--------------|----------------|----------------|
| | | | | | FUEL \$ | MAINT O & M \$ | OTHER O & M \$ |
| Natural gas boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #2 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #6 Oil fired boiler | -- | .800 | 3.67 | .0 | 1535.1 | 165.4 | 491.1 |
| Micronized coal refit | 1 | .800 | 1.97 | 2554.4 | 824.0 | 368.2 | 674.7 |
| Slagging burner refit | 1 | .800 | 1.97 | 4442.8 | 824.0 | 368.2 | 674.7 |
| Modular FBC refit | 1 | .790 | 1.97 | 5111.7 | 834.5 | 350.4 | 650.3 |
| Stoker firing refit | 1 | .760 | 2.46 | 3034.9 | 1083.2 | 350.4 | 636.2 |
| Coal/water slurry | 1 | .750 | 3.00 | 2586.4 | 1338.5 | 350.4 | 565.7 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2131.1 | 1501.6 | 279.0 | 538.2 |
| Low Btu gasifier refit | 1 | .679 | 2.46 | 4169.9 | 1213.1 | 323.2 | 810.4 |
| Packaged shell stoker | 1 | .760 | 2.46 | 3547.4 | 1083.2 | 350.4 | 636.2 |
| Packaged shell FBC | 1 | .760 | 1.97 | 4523.8 | 867.4 | 350.4 | 650.9 |
| Field erected stoker | 1 | .800 | 2.46 | 6497.4 | 1029.0 | 348.3 | 625.7 |
| Field erected FBC | 1 | .800 | 1.97 | 7133.3 | 824.0 | 407.0 | 650.1 |
| Pulverized coal boiler | 1 | .820 | 1.97 | 7562.3 | 803.9 | 411.2 | 676.6 |
| Circulating FBC | 1 | .810 | 1.97 | 8473.6 | 813.9 | 348.3 | 716.2 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|--|------------------|---|---------------------|------------------------------------|---|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT \$ | BENEFIT/ COST RATIO | DISCOUNTED PAYBACK PERIOD, YR | LIFE CYCLE COST, DISCOUNTED AS SPENT \$ | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 0 | -- | | | |
| #2 Oil fired boiler | -- | -- | 0 | -- | | | |
| #6 Oil fired boiler | -- | -- | 28,680 | 1.000 | <--- Existing system, primary fuel | | |
| Micronized coal refit | 1 | 16,339 | 18,358 | 1.562 | 5.6 | 20,121 | 1.425 |
| Slagging burner refit | 1 | 16,339 | 19,919 | 1.440 | 8.3 | 22,645 | 1.266 |
| Modular FBC refit | 1 | 16,546 | 20,220 | 1.418 | 9.1 | 23,280 | 1.232 |
| Stoker firing refit | Not applicable because existing boiler was designed for #6 oil | | | | | | |
| Coal/water slurry | 1 | 17,429 | 22,183 | 1.293 | 9.1 | 24,070 | 1.192 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | 1 | 18,966 | 23,983 | 1.196 | 13.9 | 26,692 | 1.074 |
| Packaged shell stoker | 1 | 16,935 | 21,141 | 1.357 | 8.8 | 23,467 | 1.222 |
| Packaged shell FBC | 1 | 17,199 | 20,047 | 1.431 | 8.5 | 22,816 | 1.257 |
| Field erected stoker | 1 | 16,088 | 22,972 | 1.248 | 13.4 | 26,785 | 1.071 |
| Field erected FBC | 1 | 16,339 | 22,298 | 1.286 | 12.8 | 26,401 | 1.086 |
| Pulverized coal boiler | 1 | 15,941 | 22,709 | 1.263 | 13.7 | 27,033 | 1.061 |
| Circulating FBC | 1 | 16,138 | 23,301 | 1.231 | 15.0 | 28,085 | 1.021 |

PLATTSBURGH AFB: 1 X 50 MBtu/hr. FUEL REAL ESCALATION = APO 1987

Total steam output = 50.0 MBtu/hr

Boiler capacity factor = .764

Number of units for refit = 1

Hydrated lime price (\$/ton) = 40.00

Ash disposal price (\$/ton) = 10.00

Electric price (cents/kWh) = 6.30

Labor rate (\$/yr) = 35.00

Limestone price (\$/ton) = 20.00

FUEL PRICES

Natural gas price (\$/MBtu) = .00

#2 Oil price (\$/MBtu) = .00

#6 Oil price (\$/MBtu) = 3.67

OPTIONS

Soot blower multiplier = .0

Tube bank mod multiplier = 1.0

Bottom ash pit multiplier = 1.0

SO2 control multiplier = .0

LIMESTONE/LIME

Inert fraction = .05

COAL PROPERTIESR.O.M. Stoker

Ash fraction = .090 .050

Sulfur fraction = .020 .020

HHV (Btu/lb) = 12800. 13000.

FUEL PRICES

R.O.M. coal (\$/MBtu) = 1.97

Stoker coal (\$/MBtu) = 2.46

Coal/H2O mix (\$/MBtu) = 3.00

Coal/oil mix (\$/MBtu) = 3.50

Primary fuel is 1

#6 FUEL OIL

1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988

Gen infla index (1987 to base yr) = 1.040

Gas infla index (1988 to base yr) = 1.000

Oil infla index (1988 to base yr) = 1.000

Coal infla index (1988 to base yr) = 1.000

Project start year = 1990

Project life (yr) = 30

Depreciation life (yr) = 15

General inflation rate (I/yr) = 0

Type of gas escalation = egas

Type of oil escalation = eoil

Type of coal escalation = ecoal

Discount rate (I/yr) = 10

Rate of return on invest (I/yr) = 17

Amount of working capital (month) = 2

Federal income tax rate (I) = 34

Local prop tax (& insur) rate (I) = 2

| | | <u>REAL ESCALATION RATE (I/yr)</u> | | | |
|-------------|--------------------------------|------------------------------------|-------|-------|----------|
| <u>FUEL</u> | <u>TYPE OF FUEL ESCALATION</u> | 1988 | 1990 | 1995 | 2000 AND |
| | | -1990 | -1995 | -2000 | BEYOND |
| Gas | egas | 2.28 | 4.70 | 5.49 | 2.75 |
| Oil | eoil | .17 | 4.16 | 5.55 | 2.77 |
| Coal | ecoal | 1.46 | 1.76 | 1.61 | .81 |

11:48 AM Jan 11, 1989

PLATTSBURGH AFB: 1 X 50 MBtu/hr. FUEL REAL ESCALATION - AEO 1987

Total steam output = 50.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .784

Primary fuel = #6 FUEL OIL

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL \$K | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL \$K | MAINT O & M \$K | OTHER O & M \$K |
| Natural gas boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #2 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #6 Oil fired boiler | -- | .800 | 3.67 | .0 | 1532.1 | 165.4 | 491.1 |
| Micronized coal refit | 1 | .800 | 1.97 | 2554.4 | 824.0 | 368.2 | 674.7 |
| Slagging burner refit | 1 | .800 | 1.97 | 4442.8 | 824.0 | 368.2 | 674.7 |
| Modular FBC refit | 1 | .790 | 1.97 | 5111.7 | 834.5 | 350.4 | 650.3 |
| Stoker firing refit | 1 | .760 | 2.46 | 5714.9 | 1083.2 | 350.4 | 636.2 |
| Coal/water slurry | 1 | .750 | 3.00 | 2583.4 | 1338.5 | 350.4 | 563.7 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2131.1 | 1501.6 | 278.0 | 538.2 |
| Low Btu gasifier refit | 1 | .679 | 2.43 | 4169.9 | 1213.1 | 323.2 | 610.4 |
| Packaged shell stoker | 1 | .760 | 2.46 | 3547.4 | 1083.2 | 350.4 | 636.2 |
| Packaged shell FBC | 1 | .760 | 1.97 | 4523.8 | 867.4 | 350.4 | 650.9 |
| Field erected stoker | 1 | .800 | 2.46 | 6497.4 | 1029.0 | 348.3 | 625.7 |
| Field erected FBC | 1 | .800 | 1.97 | 7233.3 | 824.0 | 407.0 | 650.1 |
| Pulverized coal boiler | 1 | .820 | 1.97 | 7562.3 | 803.9 | 411.2 | 676.6 |
| Circulating FBC | 1 | .810 | 1.97 | 8473.6 | 813.9 | 348.3 | 716.2 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AEP FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|--|------------------|--|---------------------|------------------------------------|--|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT \$K | BENEFIT/ COST RATIO | DISCOUNTED PERIOD, Yr | LIFE CYCLE COST, DISCOUNTED AS SPENT \$K | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 0 | -- | | | |
| #2 Oil fired boiler | -- | -- | 0 | -- | | | |
| #6 Oil fired boiler | -- | -- | 23,343 | 1.000 | <--- Existing system, primary fuel | | |
| Micronized coal refit | 1 | 16,339 | 18,227 | 1.281 | 8.7 | 19,987 | 1.168 |
| Slagging burner refit | 1 | 16,339 | 19,788 | 1.180 | 13.4 | 22,510 | 1.037 |
| Modular FBC refit | 1 | 16,546 | 20,087 | 1.162 | 14.6 | 23,144 | 1.009 |
| Stoker firing refit | Not applicable because existing boiler was designed for #6 oil | | | | | | |
| Coal/water slurry | 1 | 17,429 | 21,970 | 1.062 | 19.7 | 23,852 | .979 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | 1 | 18,966 | 23,790 | .981 | >31 | 26,493 | .881 |
| Packaged shell stoker | 1 | 16,935 | 20,869 | 1.113 | 16.1 | 23,290 | 1.002 |
| Packaged shell FBC | 1 | 17,199 | 19,909 | 1.172 | 13.8 | 22,674 | 1.029 |
| Field erected stoker | 1 | 16,088 | 22,809 | 1.023 | 26.6 | 26,617 | .877 |
| Field erected FBC | 1 | 15,339 | 22,167 | 1.053 | 23.1 | 26,266 | .889 |
| Pulverized coal boiler | 1 | 15,941 | 22,581 | 1.034 | 25.4 | 26,901 | .868 |
| Circulating FBC | 1 | 16,138 | 23,172 | 1.007 | 29.6 | 27,951 | .835 |

11:48 AM Jan 11, 1989

PLATTSBURGH AFB: 1 X 50 MBtu/hr. FUEL REAL ESCALATION = ZERO

Total steam output = 50.0 MBtu/hr

Boiler capacity factor = .764

Number of units for refit = 1

Hydrated lime price (\$/ton) = 40.00

Ash disposal price (\$/ton) = 10.00

Electric price (cents/kWh) = 6.30

Labor rate (k\$/yr) = 35.00

Limestone price (\$/ton) = 20.00

FUEL PRICES

Natural gas price (\$/MBtu) = .60

#2 Oil price (\$/MBtu) = .60

#6 Oil price (\$/MBtu) = 3.67

OPTIONS

Soot blower multiplier = .0

Tube bank mod multiplier = 1.0

Bottom ash pit multiplier = 1.0

SO2 control multiplier = .0

LIMESTONE/LIME

Inert fraction = .05

COAL PROPERTIESR.O.M. Stoker

Ash fraction = .090 .080

Sulfur fraction = .020 .020

HHV (Btu/lb) = 12600. 13000.

FUEL PRICES

R.O.M. coal (\$/MBtu) = 1.97

Stoker coal (\$/MBtu) = 2.46

Coal/H2O mix (\$/MBtu) = 3.00

Coal/oil mix (\$/MBtu) = 3.50

Primary fuel is 1

#6 FUEL OIL

1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988

Gen infla index (1987 to base yr) = 1.040

Gas infla index (1988 to base yr) = 1.000

Oil infla index (1988 to base yr) = 1.000

Coal infla index (1988 to base yr) = 1.000

Project start year = 1990

Project life (yr) = 30

Depreciation life (yr) = 15

General inflation rate (I/yr) = 0

Type of gas escalation = zero

Type of oil escalation = zero

Type of coal escalation = zero

Discount rate (I/yr) = 10

Rate of return on invest (I/yr) = 17

Amount of working capital (month) = 2

Federal income tax rate (I) = 34

Local prop tax (& insur) rate (I) = 2

| FUEL | TYPE OF FUEL ESCALATION | REAL ESCALATION RATE (I/yr) | | | |
|------|----------------------------|-----------------------------|---------------|---------------|--------------------|
| | | 1988 -1990 | 1990 -1995 | 1995 -2000 | 2000 AND BEYOND |
| Gas | zero | 0 | 0 | 0 | 0 |
| Oil | zero | 0 | 0 | 0 | 0 |
| Coal | zero | 0 | 0 | 0 | 0 |

11:52 AM Jan 11, 1989

PLATTSBURGH AFB: 1 X 50 MBtu/hr. FUEL REAL ESCALATION = ZERO

Total steam output = 50.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .764

Primary fuel = #6 FUEL OIL

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | OTHER O & M k\$ |
| Natural gas boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #2 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #6 Oil fired boiler | -- | .800 | 3.67 | .0 | 1535.1 | 165.4 | 491.1 |
| Micronized coal refit | 1 | .800 | 1.97 | 2354.4 | 824.0 | 368.2 | 674.7 |
| Slagging burner refit | 1 | .800 | 1.97 | 4442.8 | 824.0 | 368.2 | 674.7 |
| Modular FBC refit | 1 | .790 | 1.97 | 5111.7 | 834.3 | 350.4 | 650.3 |
| Stoker firing refit | 1 | .760 | 2.46 | 3034.9 | 1083.2 | 350.4 | 636.2 |
| Coal/water slurry | 1 | .750 | 3.00 | 2586.4 | 1338.5 | 350.4 | 565.7 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2131.1 | 1501.6 | 279.0 | 538.2 |
| Low Btu gasifier refit | 1 | .679 | 2.46 | 4769.9 | 1213.1 | 323.2 | 810.4 |
| Packaged shell stoker | 1 | .760 | 2.46 | 3547.4 | 1083.2 | 350.4 | 636.2 |
| Packaged shell FBC | 1 | .760 | 1.97 | 4523.8 | 867.4 | 350.4 | 650.9 |
| Field erected stoker | 1 | .800 | 2.46 | 6497.4 | 1029.0 | 348.3 | 625.7 |
| Field erected FBC | 1 | .800 | 1.97 | 7133.3 | 824.0 | 407.0 | 650.1 |
| Pulverized coal boiler | 1 | .820 | 1.97 | 7562.3 | 803.9 | 411.2 | 676.6 |
| Circulating FBC | 1 | .810 | 1.97 | 8473.6 | 813.9 | 348.3 | 716.2 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|--|------------------|--|---------------------|------------------------------------|-------------------------|---------------------|
| | | | LIFE CYCLE COST, DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO | DISCOUNTED PAYBACK PERIOD. yr | DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO |
| Natural gas boiler | -- | -- | 0 | -- | | | |
| #2 Oil fired boiler | -- | -- | 0 | -- | | | |
| #6 Oil fired boiler | -- | -- | 17,265 | 1.000 | <--- Existing system, primary fuel | | |
| Micronized coal refit | 1 | 16,339 | 17,079 | 1.011 | 21.3 | 18,806 | .918 |
| Slagging burner refit | 1 | 16,339 | 18,640 | .926 | >31 | 21,330 | .809 |
| Modular FBC refit | 1 | 16,546 | 18,925 | .912 | >31 | 21,949 | .787 |
| Stoker firing refit | Not applicable because existing boiler was designed for #6 oil | | | | | | |
| Coal/water slurry | 1 | 17,429 | 20,106 | .859 | >31 | 21,934 | .787 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | 1 | 18,966 | 22,101 | .781 | >31 | 24,756 | .697 |
| Packaged shell stoker | 1 | 16,935 | 19,461 | .887 | >31 | 21,738 | .794 |
| Packaged shell FBC | 1 | 17,199 | 18,701 | .923 | >31 | 21,432 | .806 |
| Field erected stoker | 1 | 15,088 | 21,375 | .808 | >31 | 25,143 | .687 |
| Field erected FBC | 1 | 16,339 | 21,019 | .821 | >31 | 25,086 | .688 |
| Pulverized coal boiler | 1 | 15,841 | 21,462 | .804 | >31 | 25,750 | .671 |
| Circulating FBC | 1 | 16,138 | 22,038 | .783 | >31 | 26,786 | .645 |

11:52 AM Jan 11, 1989

USAF ACADEMY: USAFA

1. BACKGROUND

The USAF Academy is located 10 miles north of Colorado Springs, Colorado. There are two boiler plants of significance at the Academy, both of which produce pressurized hot water. Natural gas is the primary fuel, and No. 5 fuel oil (150,000 MBtu/gal) is the reserve fuel. All boilers are water-tube type, and were designed for No. 5 oil/gas firing. Only plant No. 2560 was considered in the LCC analysis. The yearly average fuel use at plant No. 2560 is roughly 64 MBtu/h.

2. HEATING PLANT UNITS

Heating Plant No. 2560:

3 x 100 MBtu/h, Combustion Engineering, 1957
80 MBtu/h, Boiler Engineering and Supply Co., 1968

Heating Plant No. 8026:

2 x 30 MBtu/h, Combustion Engineering, 1957

3. IDEAL CAPACITY FACTOR ANALYSIS

The ideal capacity factors listed below were calculated from monthly fuel-use data for plant No. 2560.

| Fuel input (MBtu/h) | FY 1986 ideal capacity factor | FY 1987 ideal capacity factor |
|---------------------------|--|--|
| 50 | 0.87 | 0.90 |
| 60 | 0.82 | 0.86 |
| 70 | 0.79 | 0.81 |
| 80 | 0.75 | 0.76 |
| 90 | 0.70 | 0.72 |
| 100 | 0.64 | 0.65 |
| 110 | 0.58 | 0.59 |

4. ENERGY PRICES

FY 1986 Price Data:

Electricity = 3.5¢/kWh at year end
Natural gas = \$3.8/MBtu
No. 5 oil = very little purchased

C. H. Guernsey and Co. Survey:

Electricity = 3.5¢/kWh
 Natural gas = \$3.5/MBtu
 No. 5 oil = no value given

Letter from USAF Academy (10/5/88):

Electricity = 3.76¢/kWh
 Natural gas = \$2.56/MBtu
 No. 5 oil = \$0.65/gal = \$4.33/MBtu

The gas contract is interruptible, but the gas supply is rarely interrupted.

5. COAL PROPERTIES AND PRICES

| | <u>Stoker</u> | <u>ROM</u> |
|-------------------------------------|---------------|--------------|
| Origin | Axial, Colo. | Axial, Colo. |
| HHV, Btu/lb | 11,000 | 10,700 |
| % Ash | 4.3 | 4.9 |
| % Sulfur | 0.42 | 0.36 |
| % Nitrogen | 1.39 | 1.39 |
| Ash-softening temperature, °F | 2300 | 2300 |
| Swelling index | 0 | 0 |
| Top size, in. | 1 1/2 | 2 |
| Bottom size, in. | 3/8 | 0 |
| Fines, % | | 10-15 |
| Grindability index | 50 | 50 |
| Cost at mine, \$/ton | 22 | 15 |
| Delivered cost, \$/ton | 32 | 25 |
| Energy cost, \$/10 ⁶ Btu | 1.45 | 1.17 |

6. ENVIRONMENTAL REGULATIONS

6.1 Air Pollution Emission Limits for New Sources

SO₂. No emission limits for boilers <100 MBtu/h; for boilers >100 MBtu/h: FBC - 90% reduction to meet limit of 1.2 lb/MBtu; emerging technology - 50% reduction to meet limit of 0.6 lb/MBtu.

NO_x. No emission limits for boilers <100 MBtu/h; for boilers >100 MBtu/h: spreader stoker and FBC - 0.6 lb/MBtu; pulverized coal - 0.7 lb/MBtu.

Particulates. For boilers >100 MBt 0.05 lb/MBtu.

6.2 Coal-Pile Runoff

Limit: Total suspended solids - 50 mg/L.

6.3 Ash Disposal

Ashes may be disposed of in special disposal sites owned by private contractors with a permit called "Certificate of Designation."

7. OTHER CONSIDERATIONS

Heat plant No. 2560 is capable of producing 425 psig hot water but operates at about 185 psig. The design pressure for heat plant No. 8026 is 275 psig.

8. COAL-CONVERSION PROJECT OUTLOOK

A coal refit/replacement project would involve the 80-MBtu/h output (~100-MBtu/h fuel input) unit in plant No. 2560. The overall capacity factor for a project of this size is estimated to be 58%, assuming 90% availability.

8.1 Effect of Environmental Regulations on Selection of Combustion Technologies

SO₂ and NO_x. Any of the combustion technologies being considered could be employed without requiring any measures for NO_x or SO₂ reduction since the proposed conversion project is smaller than 100 MBtu/h.

Particulates. Bag filters or electrostatic precipitators would be required to comply with the particulate emission limits.

8.2 Physical Space and Aesthetics

Heating Plant. The existing boiler plant was originally designed for No. 5 oil. There is only space available for installing coal-water-mixture combustion equipment at the existing boiler or for construction of a new boiler at another site on base.

Coal-Handling Equipment. There is no space available for installing dry coal-handling equipment at the existing boiler plant, but there is enough space for installing coal-water-mixture equipment.

Coal Pile. There is no space available for a coal pile at the existing boiler plant, but there is space at another site on base for a coal pile and a new coal-fired boiler.

8.3 Technical Risk of Combustion Technologies

The existing boilers are designed for No. 5 oil or gas firing. The technical risk is fairly high because of limited experience of coal-water-mixture firing of No. 5 oil-designed boilers.

9. COGENERATION PROJECT OUTLOOK

Cogeneration would probably not be economical at this base because of the low electric power rates.

10. INPUT AND LCC SUMMARY SPREADSHEETS

USAF ACADEMY: 1 X 80 MBtu/hr. ECONOMIC PARAMETERS - NOMINAL VALUES

Total steam output = 80.0 MBtu/hr
 Boiler capacity factor = .580
 Number of units for refit = 1
 Hydrated lime price (\$/ton) = 40.00
 Ash disposal price (\$/ton) = 10.00
 Electric price (cents/kWh) = 3.60
 Labor rate (\$/hr) = 35.00
 Limestone price (\$/ton) = 20.00

FUEL PRICES
 Natural gas price (\$/MBtu) = 2.56
 #2 Oil price (\$/MBtu) = .00
 #6 Oil price (\$/MBtu) = 3.67

COAL PROPERTIES
 R.O.M. Stoker
 Ash fraction = .049 .043
 Sulfur fraction = .004 .004
 HHV (Btu/lb) = 10700. 11000.

FUEL PRICES
 R.O.M. coal (\$/MBtu) = 1.17
 Stoker coal (\$/MBtu) = 1.45
 Coal/H₂O mix (\$/MBtu) = 3.00
 Coal/oil mix (\$/MBtu) = 3.50

OPTIONS
 Soot blower multiplier = 1.0
 Tube bank mod multiplier = 1.0
 Bottom ash pit multiplier = 1.0
 SO₂ control multiplier = .0

LIMESTONE/LIME
 Inert fraction = .05

ECONOMIC PARAMETERS
 Inflation & discounting base year = 1988
 Gen infla index (1987 to base yr) = 1.040
 Gas infla index (1988 to base yr) = 1.000
 Oil infla index (1988 to base yr) = 1.000
 Coal infla index (1988 to base yr) = 1.000
 Project start year = 1990
 Project life (yr) = 30
 Depreciation life (yr) = 15
 General inflation rate (I/yr) = 0
 Type of gas escalation = egas
 Type of oil escalation = eoil
 Type of coal escalation = ecoal
 Discount rate (I/yr) = 10
 Rate of return on invest (I/yr) = 17
 Amount of working capital (month) = 2
 Federal income tax rate (I) = 34
 Local prop tax (& insur) rate (I) = 2

Primary fuel is 3
 NATURAL GAS
 1-#6 Oil, 2-#2 Oil, 3-NG

| | | REAL ESCALATION RATE (I/yr) | | | |
|------|----------------------------|-----------------------------|-------|-------|--------------------|
| FUEL | TYPE OF FUEL ESCALATION | 1988 | 1990 | 1995 | 2000 AND BEYOND |
| | | -1990 | -1995 | -2000 | |
| Gas | egas | 3.89 | 8.87 | 5.77 | 5.77 |
| Oil | eoil | 4.86 | 7.87 | 4.16 | 4.16 |
| Coal | ecoal | 1.16 | 2.31 | 1.19 | 1.19 |

10:57 AM Oct 24, 1988

USAF ACADEMY: 1 X 80 MBtu/hr. ECONOMIC PARAMETERS - NOMINAL VALUES

Total steam output = 80.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .583

Primary fuel = NATURAL GAS

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | OTHER O & M k\$ |
| | | | | | k\$ | k\$ | k\$ |
| Natural gas boiler | -- | .800 | 2.56 | .0 | 1360.7 | 214.2 | 522.7 |
| #2 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #6 Oil fired boiler | -- | .800 | 3.67 | .0 | 1864.7 | 214.2 | 522.7 |
| Micronized coal refit | 1 | .800 | 1.17 | 3469.2 | 594.5 | 436.9 | 692.0 |
| Slagging burner refit | 1 | .800 | 1.17 | 5951.8 | 594.5 | 436.9 | 692.0 |
| Modular FBC refit | 1 | .790 | 1.17 | 6828.9 | 602.0 | 415.0 | 675.1 |
| Stoker firing refit | 1 | .760 | 1.45 | 3815.8 | 775.5 | 415.0 | 665.0 |
| Coal/water slurry | 1 | .750 | 3.00 | 3552.0 | 1625.9 | 415.0 | 587.8 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2996.5 | 1823.9 | 330.5 | 560.6 |
| Low Btu gasifier refit | 2 | .679 | 1.45 | 6668.1 | 868.5 | 382.8 | 901.1 |
| Packaged shell stoker | 2 | .760 | 1.45 | 5720.5 | 775.5 | 415.0 | 762.4 |
| Packaged shell FBC | 2 | .760 | 1.17 | 7205.4 | 625.7 | 415.0 | 773.0 |
| Field erected stoker | 1 | .800 | 1.45 | 8363.7 | 736.7 | 412.5 | 656.6 |
| Field erected FBC | 1 | .800 | 1.17 | 9561.0 | 594.5 | 482.0 | 675.0 |
| Pulverized coal boiler | 1 | .820 | 1.17 | 10107.7 | 580.0 | 487.6 | 706.6 |
| Circulating FBC | 1 | .810 | 1.17 | 11575.8 | 587.1 | 412.5 | 734.1 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|--|------------------|-------------------------------|---------------------|------------------------------------|-------------------------|---------------------|
| | | | LIFE CYCLE COST, AS SPENT k\$ | BENEFIT/ COST RATIO | DISCOUNTED PAYBACK PERIOD, yr | DISCOUNTED AS SPENT k\$ | BENEFIT/ COST RATIO |
| | | | k\$ | RATIO | yr | k\$ | RATIO |
| Natural gas boiler | -- | -- | 28,827 | 1.000 | <--- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 0 | -- | | | |
| #6 Oil fired boiler | -- | -- | 34,380 | -- | | | |
| Micronized coal refit | Not applicable because of space limitations | | | | | | |
| Slagging burner refit | Not applicable because of space limitations | | | | | | |
| Modular FBC refit | Not applicable because of space limitations | | | | | | |
| Stoker firing refit | Not applicable because existing boiler was designed for #5 oil | | | | | | |
| Coal/water slurry | 1 | 25,325 | 26,416 | 1.091 | 22.7 | 26,892 | .996 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | Not applicable because of space limitations | | | | | | |
| Packaged shell stoker | 2 | 24,310 | 21,623 | 1.333 | 13.3 | 25,020 | 1.152 |
| Packaged shell FBC | 2 | 24,992 | 21,534 | 1.339 | 13.9 | 25,651 | 1.124 |
| Field erected stoker | 1 | 23,095 | 22,847 | 1.262 | 16.4 | 27,710 | 1.040 |
| Field erected FBC | 1 | 23,742 | 23,024 | 1.252 | 17.1 | 28,329 | 1.018 |
| Pulverized coal boiler | 1 | 23,163 | 23,632 | 1.220 | 18.3 | 29,220 | .987 |
| Circulating FBC | 1 | 23,449 | 24,460 | 1.179 | 20.1 | 30,786 | .936 |

USAF ACADEMY: 1 X 80 MBtu/hr. FUEL REAL ESCALATION ~ AEO 1987

Total steam output = 80.0 MBtu/hr

Boiler capacity factor = .580

Number of units for refit = 1

Hydrated lime price (\$/ton) = 40.00

Ash disposal price (\$/ton) = 10.00

Electric price (cents/kwh) = 3.60

Labor rate (k\$/yr) = 35.00

Limestone price (\$/ton) = 20.00

FUEL PRICES

Natural gas price (\$/MBtu) = 2.56

#2 Oil price (\$/MBtu) = .00

#6 Oil price (\$/MBtu) = 3.67

OPTIONS

Soot blower multiplier = 1.0

Tube bank mod multiplier = 1.0

Bottom ash pit multiplier = 1.0

SO2 control multiplier = .0

LIMESTONE/LIME

Inert fraction = .05

COAL PROPERTIES

R.O.M. Stoker

Ash fraction = .049 .043

Sulfur fraction = .004 .004

HHV (Btu/lb) = 10700. 11000.

FUEL PRICES

R.O.M. coal (\$/MBtu) = 1.17

Stoker coal (\$/MBtu) = 1.45

Coal/H2O mix (\$/MBtu) = 3.00

Coal/oil mix (\$/MBtu) = 3.50

Primary fuel is 3

NATURAL GAS

1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988

Gen infla index (1987 to base yr) = 1.040

Gas infla index (1988 to base yr) = 1.000

Oil infla index (1988 to base yr) = 1.000

Coal infla index (1988 to base yr) = 1.000

Project start year = 1990

Project life (yr) = 30

Depreciation life (yr) = 15

General inflation rate (X/yr) = 0

Type of gas escalation = egas

Type of oil escalation = eoil

Type of coal escalation = ecoal

Discount rate (X/yr) = 10

Rate of return on invest (X/yr) = 17

Amount of working capital (month) = 2

Federal income tax rate (X) = 34

Local prop tax (& insur) rate (X) = 2

| | | <u>REAL ESCALATION RATE (X/yr)</u> | | | |
|-------------|------------------------------------|------------------------------------|-------|-------|----------|
| <u>FUEL</u> | <u>TYPE OF FUEL ESCALATION</u> | 1988 | 1990 | 1995 | 2000 AND |
| | | -1990 | -1995 | -2000 | BEYOND |
| Gas | egas | 2.28 | 4.70 | 5.49 | 2.75 |
| Oil | eoil | .17 | 4.16 | 5.55 | 2.77 |
| Coal | ecoal | 1.46 | 1.76 | 1.61 | .81 |

11:05 AM Oct 24, 1988

USAF ACADEMY: 1 X 80 MBtu/hr. FUEL REAL ESCALATION = AEO 1987

Total steam output = 80.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .580

Primary fuel = NATURAL GAS

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL k\$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|-------------------|--------------|-----------------|-----------------|
| | | | | | FUEL k\$ | MAINT O & M k\$ | OTHER O & M k\$ |
| Natural gas boiler | -- | .800 | 2.55 | .0 | 1300.7 | 214.2 | 522.7 |
| #2 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #6 Oil fired boiler | -- | .800 | 3.67 | .0 | 1864.7 | 214.2 | 522.7 |
| Micronized coal refit | 1 | .800 | 1.17 | 3469.2 | 594.5 | 438.9 | 692.0 |
| Slagging burner refit | 1 | .800 | 1.17 | 5951.8 | 594.5 | 438.9 | 692.0 |
| Modular FBC refit | 1 | .790 | 1.17 | 8828.9 | 602.0 | 415.0 | 675.1 |
| Stoker firing refit | 1 | .760 | 1.45 | 3815.8 | 775.5 | 415.0 | 665.0 |
| Coal/water slurry | 1 | .750 | 3.00 | 3552.0 | 1625.9 | 415.0 | 587.8 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2985.5 | 1823.0 | 330.5 | 560.6 |
| Low Btu gasifier refit | 2 | .679 | 1.45 | 8668.1 | 868.5 | 382.8 | 901.1 |
| Packaged shell stoker | 2 | .760 | 1.45 | 5720.5 | 775.5 | 415.0 | 762.4 |
| Packaged shell FBC | 2 | .760 | 1.17 | 7205.4 | 625.7 | 415.0 | 773.0 |
| Field erected stoker | 1 | .800 | 1.45 | 8863.7 | 736.7 | 412.5 | 656.6 |
| Field erected FBC | 1 | .800 | 1.17 | 9561.0 | 594.5 | 482.0 | 675.0 |
| Pulverized coal boiler | 1 | .820 | 1.17 | 10107.7 | 580.0 | 487.0 | 706.6 |
| Circulating FBC | 1 | .810 | 1.17 | 11572.8 | 587.1 | 412.5 | 734.1 |

| TECHNOLOGY | # OF UNITS | COAL USE, ton/yr | AIR FORCE PROJECT | | | PRIVATE PROJECT | |
|------------------------|--|------------------|---------------------|---------------------|------------------------------------|---------------------|---------------------|
| | | | LIFE CYCLE COST, | BENEFIT/ COST RATIO | DISCOUNTED PAYBACK PERIOD, Yr | LIFE CYCLE COST, | BENEFIT/ COST RATIO |
| | | | DISCOUNTED AS SPENT | | | DISCOUNTED AS SPENT | |
| | | | k\$ | | | k\$ | |
| Natural gas boiler | -- | -- | 22,246 | 1.000 | <--- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 0 | -- | | | |
| #6 Oil fired boiler | -- | -- | 27,897 | -- | | | |
| Micronized coal refit | Not applicable because of space limitations | | | | | | |
| Slagging burner refit | Not applicable because of space limitations | | | | | | |
| Modular FBC refit | Not applicable because of space limitations | | | | | | |
| Stoker firing refit | Not applicable because existing boiler was designed for #5 oil | | | | | | |
| Coal/water slurry | 1 | 25,325 | 26,157 | .850 | >31 | 28,627 | .777 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | Not applicable because of space limitations | | | | | | |
| Packaged shell stoker | 2 | 24,310 | 21,500 | 1.035 | 24.7 | 24,893 | .894 |
| Packaged shell FBC | 2 | 24,992 | 21,435 | 1.038 | 24.8 | 25,548 | .871 |
| Field erected stoker | 1 | 23,095 | 22,730 | .979 | >31 | 27,589 | .806 |
| Field erected FBC | 1 | 23,742 | 22,929 | .970 | >31 | 28,232 | .788 |
| Pulverized coal boiler | 1 | 23,163 | 23,540 | .945 | >31 | 29,125 | .764 |
| Circulating FBC | 1 | 23,449 | 24,366 | .913 | >31 | 30,690 | .725 |

USAF ACADEMY: 1 X 80 MBtu/hr. FUEL REAL ESCALATION = ZERO

Total steam output = 80.0 MBtu/hr

Boiler capacity factor = .580

Number of units for refit = 1

Hydrated lime price (\$/ton) = 40.00

Ash disposal price (\$/ton) = 10.00

Electric price (cents/kWh) = 3.60

Labor rate (k\$/yr) = 35.00

Limestone price (\$/ton) = 20.00

FUEL PRICES

Natural gas price (\$/MBtu) = 2.56

#2 Oil price (\$/MBtu) = .00

#6 Oil price (\$/MBtu) = 3.67

OPTIONS

Soot blower multiplier = 1.0

Tube bank mod multiplier = 1.0

Bottom ash pit multiplier = 1.0

SO2 control multiplier = .0

LIMESTONE/LIME

Inert fraction = .05

COAL PROPERTIESR.O.M. Stoker

Ash fraction = .049 .043

Sulfur fraction = .004 .004

HHV (Btu/lb) = 10700. 11000.

FUEL PRICES

R.O.M. coal (\$/MBtu) = 1.17

Stoker coal (\$/MBtu) = 1.45

Coal/H2O mix (\$/MBtu) = 3.00

Coal/oil mix (\$/MBtu) = 3.50

Primary fuel is 3

NATURAL GAS

1-#6 Oil, 2-#2 Oil, 3-NG

ECONOMIC PARAMETERS

Inflation & discounting base year = 1988

Gen infla index (1987 to base yr) = 1.040

Gas infla index (1988 to base yr) = 1.000

Oil infla index (1988 to base yr) = 1.000

Coal infla index (1988 to base yr) = 1.000

Project start year = 1990

Project life (yr) = 30

Depreciation life (yr) = 15

General inflation rate (I/yr) = 0

Type of gas escalation = zero

Type of oil escalation = zero

Type of coal escalation = zero

Discount rate (I/yr) = 10

Rate of return on invest (I/yr) = 17

Amount of working capital (month) = 2

Federal income tax rate (I) = 34

Local prop tax (& insur) rate (I) = 2

| FUEL | TYPE OF FUEL ESCALATION | REAL ESCALATION RATE (I/yr) | | | |
|------|----------------------------|-----------------------------|---------------|---------------|--------------------|
| | | 1988 -1990 | 1990 -1995 | 1995 -2000 | 2000 AND BEYOND |
| Gas | zero | 0 | 0 | 0 | 0 |
| Oil | zero | 0 | 0 | 0 | 0 |
| Coal | zero | 0 | 0 | 0 | 0 |

11:11 AM Oct 24, 1988

USAF ACADEMY: 1 X 80 MBtu/hr. FUEL REAL ESCALATION = ZERO

Total steam output = 80.0 MBtu/hr

Cost base year = 1988

Boiler capacity factor = .580

Primary fuel = NATURAL GAS

Number of units for refit = 1

| TECHNOLOGY | # OF UNITS | FUEL/ STEAM EFF | FUEL PRICE \$/MBtu | TOTAL CAPITAL \$ | ANNUAL COSTS | | |
|------------------------|------------|-----------------|--------------------|------------------|--------------|----------------|----------------|
| | | | | | FUEL \$ | MAINT O & M \$ | OTHER O & M \$ |
| Natural gas boiler | -- | .800 | 2.56 | .0 | 1300.7 | 214.2 | 522.7 |
| #2 Oil fired boiler | -- | .800 | .00 | .0 | .0 | .0 | .0 |
| #6 Oil fired boiler | -- | .800 | 3.67 | .0 | 1864.7 | 214.2 | 522.7 |
| Micronized coal refit | 1 | .800 | 1.17 | 3469.2 | 594.5 | 436.9 | 692.0 |
| Slagging burner refit | 1 | .800 | 1.17 | 5951.6 | 594.5 | 436.9 | 692.0 |
| Modular FBC refit | 1 | .780 | 1.17 | 6828.9 | 602.0 | 415.0 | 675.1 |
| Stoker firing refit | 1 | .760 | 1.45 | 3815.8 | 775.5 | 415.0 | 665.0 |
| Coal/water slurry | 1 | .750 | 3.00 | 3552.0 | 1825.9 | 415.0 | 587.8 |
| Coal/oil slurry | 1 | .780 | 3.50 | 2986.5 | 1823.9 | 330.5 | 560.6 |
| Low Btu gasifier refit | 2 | .679 | 1.45 | 6666.1 | 666.5 | 382.8 | 801.1 |
| Packaged shell stoker | 2 | .780 | 1.45 | 5720.5 | 775.5 | 415.0 | 762.4 |
| Packaged shell FBC | 2 | .760 | 1.17 | 7205.4 | 625.7 | 415.0 | 773.0 |
| Field erected stoker | 1 | .800 | 1.45 | 8663.7 | 736.7 | 412.5 | 656.8 |
| Field erected FBC | 1 | .800 | 1.17 | 9561.0 | 594.5 | 482.0 | 675.0 |
| Pulverized coal boiler | 1 | .820 | 1.17 | 10107.7 | 580.0 | 487.0 | 706.6 |
| Circulating FBC | 1 | .810 | 1.17 | 11575.8 | 587.1 | 412.5 | 734.1 |

| AIR FORCE PROJECT | | | | | | PRIVATE PROJECT | |
|------------------------|--|----------------|------------------------|---------------|------------------------------------|------------------------|---------------|
| | | | LIFE CYCLE COST, | | | LIFE CYCLE COST, | |
| | # OF | COAL | DISCOUNTED | BENEFIT/ | PAYBACK | DISCOUNTED | BENEFIT/ |
| TECHNOLOGY | UNITS | USE, ton/yr | AS SPENT | COST RATIO | PERIOD, yr | AS SPENT | COST RATIO |
| | | | \$ | | | \$ | |
| Natural gas boiler | -- | -- | 16,122 | 1.000 | <--- Existing system, primary fuel | | |
| #2 Oil fired boiler | -- | -- | 0 | -- | | | |
| #6 Oil fired boiler | -- | -- | 20,515 | -- | | | |
| Micronized coal refit | Not applicable because of space limitations | | | | | | |
| Slagging burner refit | Not applicable because of space limitations | | | | | | |
| Modular FBC refit | Not applicable because of space limitations | | | | | | |
| Stoker firing refit | Not applicable because existing boiler was designed for #5 oil | | | | | | |
| Coal/water slurry | 1 | 25,325 | 23,893 | .675 | >31 | 26,298 | .613 |
| Coal/oil slurry | Not evaluated | | | | | | |
| Low Btu gasifier refit | Not applicable because of space limitations | | | | | | |
| Packaged shell stoker | 2 | 24,310 | 20,420 | .790 | >31 | 23,782 | .678 |
| Packaged shell FBC | 2 | 24,892 | 20,563 | .784 | >31 | 24,652 | .654 |
| Field erected stoker | 1 | 23,095 | 21,703 | .743 | >31 | 26,534 | .608 |
| Field erected FBC | 1 | 23,742 | 22,101 | .729 | >31 | 27,380 | .589 |
| Pulverized coal boiler | 1 | 23,163 | 22,732 | .709 | >31 | 28,295 | .570 |
| Circulating FBC | 1 | 23,449 | 23,549 | .685 | >31 | 29,840 | .540 |

Internal Distribution

- | | |
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